SURFACE EROSION AND SEDIMENTATION ASSOCIATED WITH FOREST LAND USE IN INTERIOR ALASKA

by

J. W. ALDRICH and R. A. JOHNSON

INSTITUTE OF WATER RESOURCES

University of Alaska

Fairbanks, Alaska 99701

IWR-99

SURFACE EROSION AND SEDIMENTATION ASSOCIATED WITH FOREST LAND USE IN INTERIOR ALASKA

COMPLETION REPORT

James W. Aldrich
Research Assistant
and
Ronald A. Johnson
Assistant Professor
Environmental Quality Engineering

Institute of Water Resources
University of Alaska
Fairbanks, Alaska 99701

Report No. IWR-99

May, 1979

ACKNOWLEDGEMENTS

This work was supported by the Institute of Northern Forestry, Pacific Northwest Forest and Range Experiment Station, USDA. The Institute of Water Resources, University of Alaska, provided facilities for this research. The authors thank David Gaskin and Larry Johnson of the U.S. Army Cold Regions Research and Engineering Laboratory for permission to use the soil erosion plots at the Moose Creek Embankment. Assistance was also provided by Charles Slaughter and Eugene Culp of the Institute of Northern Forestry and John Fox of the Institute of Water Resources.

ABSTRACT

The magnitude of sheet-rill erosion associated with various landscape manipulations is presented. The Universal Soil Loss Equation's usefulness for predicting annual sheet-rill erosion within interior Alaska is confirmed. Investigations of sheet-rill erosion indicate that removing the trees from forested areas with only minor ground cover disturbance did not increase erosion. Removing the ground cover, however, increased erosion 18 times above that on forested areas. Erosion is substantially reduced when disturbed areas are covered with straw mulch and fertilizer. Comparison of the actual erosion and the quantity of erosion predicted with the Universal Soil Loss Equation indicates that the equation overestimates annual erosion by an average of 21 percent. It overestimates individual storm erosion by an average of 174 percent. Data are also presented concerning sheet-rill erosion in a permafrost trail, distribution of the rainfall erosion index, and suggested cover and management factor values.

TABLE OF CONTENTS

Chapter		Page

Chapter Page

LIST OF FIGURES

Figure | Page

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Background

Since soil erosion has been labeled the nation's largest pollutant of surface waters (Meyer, 1971) and sediment from logging roads is considered the number one water quality problem in the Northwest, it is imperative that the magnitude and mechanics of surface erosion begin to be studied in interior Alaska. Although timber harvesting has taken place in the Tanana and upper Yukon River valleys for more than 50 years, little is known about the effects of logging on the water quality of this region. Historically, forest utilization has been relatively slow due to climatic and transportation difficulties, and a relatively low demand for forest products. With the settlement of the Alaska Native Claims Act, however, more land will be placed into private ownership and much of the resources are likely to be harvested for export. It has been projected that the Fairbanks North Star Borough will increase in population from 63,300 in 1976 to 75,000 in 1985. Increased demands for forest products and recreation are likely to have adverse effects on water quality, unless the potential magnitude and physical processes of surface erosion are understood sufficiently well for proper land management.

While considerable time and expense have been devoted to developing timber harvesting and construction techniques specific to subarctic conditions, most of the erosion control programs have been borrowed from the contiguous United States with little consideration for conditions within interior Alaska. The current interest shown by the state of

Alaska in nonpoint source water pollution (Alaska Department of Environmental Conservation, 1977) is no different. Neither the need for nor the adaptability of these programs to subarctic conditions has been systematically studied.

1.2 Objective

The objective of this study is to investigate the magnitude of sheet-rill erosion following timber harvesting activities within interior Alaska, and to test a method of predicting sheet-rill erosion that might prove useful to future erosion control programs.

1.3 Method of Approach

In order to satisfy the objectives of this study, it is necessary to review the basic principles of soil erosion and to initiate collection of soil erosion data within interior Alaska. Although the process of soil erosion is only incompletely understood, the more apparent factors influencing erosion are presented. The Universal Soil Loss Equation, used for predicting sheet-rill erosion, is discussed in detail. A description of the research site and the methods used for data collection are also included. From plot studies, conducted by the authors during the summers of 1977 and 1978, basic soil erosion data were collected and are presented. An analysis of the data is included, along with an analysis of the Universal Soil Loss Equation for predicting sheet-rill erosion within the Interior. It is shown, quantitatively, that timber harvesting within interior Alaska can significantly increase erosion and that the Universal Soil Loss Equation is suitable for predicting sheet-rill erosion within the Interior. Finally, the need for future research is discussed.

CHAPTER 2: THE MECHANICS OF SOIL EROSION

2.1 Types of Soil Erosion

Soil erosion, as used in this report, will be defined as the detachment and transport of soil particles entrained by water (Heinemann and Piest, 1975). Sources of eroded soil may be classified according to the dominant type of erosion: sheet, rill, gully, stream channel, floodplain, or mass erosion (Foster and Meyer, 1977). Sheet erosion is the removal of a relatively thin uniform layer of soil particles from the soil surface, while rill erosion consists of erosion in numerous small channels resulting from overland flow. Gully, stream channel, and floodplain erosion all represent channel-type erosion and result from a concentrated flow of water. Mass wasting, including soil slippage and soil creep, is a special case of erosion and normally occurs only on steep slopes.

This report focuses primarily on sheet and rill erosion. Sheet-rill erosion becomes apparent to the eye at an erosion rate of 13 to 15 tons per acre per year (Kimberlin and Moldenhauer, 1977), while the geologic erosion rate for vegetated areas is commonly less than 0.3 tons per acre per year (Piest, 1970).

2.2 Factors Affecting Sheet-Rill Erosion

Since 1930, controlled studies on field plots and small watersheds have provided considerable information regarding the complex interrelationships of soil erosion. In general, it has been shown that erosion rates vary with hydrology, soils, topography, and land use.

2.2.1 Hydrology

The effects of rainfall and runoff on the soil erosion process may be described by four subprocesses: (1) detachment by rainfall, (2) transport by rainfall, (3) detachment by runoff, and (4) transport by runoff. Thus, the sediment load at a particular location along a slope is limited by one of two factors: (1) the amount of detached soil available for transport by runoff and rainfall, or (2) the combined transport capacity of the runoff and rainfall (Foster and Wischmeier, 1974).

Individual raindrops strike the soil surface at velocities up to 30 feet per second. This creates intense hydrodynamic forces at the point of impact (Mutchler and Young, 1975), and breaks down the soil aggregates. The extent to which the aggregates are broken down, the number of particles separated, and the distance the particles are transported are all functions of raindrop energy (Ellison, 1945). Although some net movement downslope occurs, the amount of detached soil transported by rainfall is small compared to that transported by runoff (Meyer et al., 1975). However, much of the soil available for transport by runoff is detached by rainfall (Meyer, 1971).

Detachment by runoff occurs primarily on that small portion of the land surface where the flow concentrates and the critical tractive force, for the existing soil conditions, is exceeded (Meyer et al., 1976). Sediment is deposited when the sediment load exceeds the flow's total transport capacity. Most of the sediment from sheet-rill erosion is transported downslope by runoff in rills (Foster and Meyer, 1977).

2.2.2 Soil

It has long been recognized that soils vary in their individual susceptibility to soil erosion. Numerous soil properties affect a soil's inherent erodibility and the individual effects of these properties are often undiscernable.

Soils that are high in silt, low in clay, and low in organic matter are generally the most easily eroded (Wischmeier and Meyer, 1973; Young, 1975). This is because silt-size particles are the most easily detached by water (Wischmeier and Meyer, 1973) and the soil pores are easily plugged, thus decreasing infiltration and increasing runoff. Furthermore, eroding soil particles classified as very fine sand behave more like silt than sand (Wischmeier and Meyer, 1973). Soils, therefore, become less erodible as the percentage of silt plus very fine sand decreases, regardless of whether the increase is in particles larger than very fine sand or smaller than silt.

The effect of soil organic matter on soil erodibility is less completely understood than the effect of grain size. Wischmeier and Meyer (1973) reported that the organic content of a soil is inversely proportional to the amount of sediment eroded, and is directly proportional to both the amount of rain needed to initiate runoff and to the saturated permeability. The ability of organic matter to decrease erosion was reported to be strongest for silts, silt loams, and sandy soils, decreasing significantly as clay content increases. While these results are generally accepted, it should be noted that the results of Meeuwig (1971) are in direct conflict with the results obtained by Wischmeier and Meyer (1973). Meeuwig (1971) found that the least erodible soils have: (1) high clay, low sand, and high organic content; (2) low clay, high sand, and low organic content; or (3) low sand regardless of organic content. Thus, it appears that other soil parameters may be capable of influencing the relationship between soil organic content and soil erosion.

Other factors known to affect the inherent erodibility of a soil include: pH, structure, bulk density, pore space filled by air, aggregation, parent material, permanent wilting point, sodium adsorption ratio, iron oxide content, and soil shear strength (Wooldridge, 1963; Balci, 1968; Foster and Martin, 1969; Wischmeier and Mannering, 1969; Cruse and Larson, 1977; Singer et al., 1978). Further complicating the analysis of a soil's inherent erodibility is the fact that the magnitude of these factors often varies from the surface to the subsurface soil.

2.2.3 Topography

Topography is one of the most important factors in describing soil erosion. It accounts for more variation in total erosion than any other factor except for possibly land use. One of the earliest researchers to study the effects of topography on soil erosion, Zingg (1940), concluded that: (1) doubling the degree of slope increased the total soil loss approximately 2.7 times, and (2) doubling the horizontal length of slope increased the total soil loss approximately three times.

It has since been shown that slope shape, as well as slope length a and gradient, has a major influence on the amount of soil eroded from a particular slope (Meyer and Kramer, 1968; Young and Mutchler, 1969). For slopes of equal average steepness, the slope shape (in cross section) which exhibits the least depth of erosion, the least eroded soil, and the least change in slope shape, is the concave slope (Meyer and Kramer, 1968). Conversely, a convex slope exhibits the greatest erosion depth, the greatest quantity of eroded soil, and the greatest change in slope shape.

The concave slope exhibits the least soil erosion because its steepest slope occurs where there is the least runoff. Its mildest slope occurs where there is the most runoff. Thus, where the slope is steep and the potential transport-detachment capacity of the runoff is highest, there is relatively little runoff. By the time there is substantial runoff, its transport-detachment capacity has been decreased by a reduction in slope steepness. In general, soil loss from irregular slopes depends primarily on the steepness of a short section of that slope immediately above the point of measurement (Young and Mutchler, 1969).

2.2.4 Land Use

The fact that land use significantly affects soil erosion has been confirmed in a number of watershed studies. Megahan (1975) reported that logged areas in central Idaho produce 1.6 times as much sediment as undisturbed forested areas, and that roads produce 220 times as much sediment. Similarly, Mansue and Anderson (1974) credit a decrease in cropland, and an increase in urban and idle land with increasing the sediment yield of the Stony Brook Basin in New Jersey. While investigating the effects of road construction on sediment yield, Fredrickson (1965) found that construction of a 1.65 mile road in a mountainous 250 acre forested watershed doubled the sediment yield of that basin in the 2 years following construction.

The effect of land use on soil erosion is primarily due to its influence on a site's inherent erodibility, topography, soil compactness, and cover. As was mentioned earlier (Section 2.2.2), the inherent erodibility of a soil can increase from the surface to the subsurface soil. Therefore, any use which might cause the subsoil to be exposed could potentially increase a site's erosion rate. Modification of a site's topography, as discussed in Section 2.2.3, is also an important influence of land use on soil erosion.

Soil compactness, as used here, refers to the loosening or compacting of the soil surface. Lusby (1965) found that although composition and percent cover remained the same in both a grazed and an ungrazed watershed, runoff and sediment yield were considerably less in the ungrazed watershed. After an investigation of the two watersheds, it was concluded that soil compaction by the grazing animals was responsible for the increased runoff and soil erosion. Conversely, loosening of the soil surface through frost action and the exclusion of grazing was shown to decrease erosion.

The effectiveness of ground cover in reducing soil erosion is associated with its ability to protect the soil surface from raindrop impact and to reduce runoff along the surface. Although there is no question that ground cover can effectively reduce soil erosion, the exact relationship of ground cover to soil erosion is not completely understood. Meeuwig (1969) reported that erosion was inversely related to the combined percentage of stone and vegetative cover. However, further rsearch (Meeuwig, 1970) indicated that in some cases the percentage of litter and vegetative cover, only, was better correlated. In studying the effectiveness of oat, straw, oak leaf, and redwood litter mulches, Singer et al. (1978) found that a single model was insufficient to accurately show the relationship between percentage of mulch cover and soil erosion. Thus, while it can be said that ground cover effectively decreases soil erosion, the magnitude of the effect seems to depend on the specific type of cover.

Unlike ground cover, canopy cover can contribute to either an increase or a decrease in soil erosion (Dohrenwend, 1977). This is due to the fact that the kinetic energy of rainfall in an open field is relatively constant for a given intensity, whereas in the forest, the kinetic energy of the raindrops increases with the height of the canopy and the size of drop formed. Hence, canopy cover will only be effective in minimizing erosion when it is low enough to produce raindrops with a kinetic energy less than that of the uninterrupted rainfall.

2.3. Empirical Relationships

2.3.1 Past Experience

Although a widely accepted deterministic model of sheet-rill erosion has yet to be developed, empirical equations for estimating soil loss have been available for many years. Zingg (1940) published an equation relating soil loss to the 1.4 power of the percent slope and the 1.6 power of the horizontal length. Later, the Musgrave Equation was developed which related soil erosion to five basic parameters: soil, slope length, slope steepness, cover, and rainfall (Musgrave, 1947). However, due to the lack of procedures for adjusting the parameters according to local variations in rainfall and cover, the equation was of little value to regions outside the area in which it was developed.

Through establishment of a national program to assemble all available runoff and soil loss data at a single location, the Universal Soil Loss Equation (Wischmeier and Smith, 1965) was developed in 1954. Refinement of the equation's parameters has continued to the present day, making it the most widely used model for predicting sheet-rill erosion in the United States.

2.3.2 The Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) is given by the expression

$$A = R \cdot K \cdot LS \cdot C \cdot P \qquad (1)$$

where

A is the computed soil loss in tons per acre,

R is a rainfall factor expressed in terms of foot-tons per acre times inches per hour, K is a soil erodibility factor expressed in tons per acre per increment of rainfall erosion index,

LS is a dimensionless topographic factor,

C is a dimensionless cover and management factor, and

P is a dimensionless erosion control practice factor.

The rainfall factor, R, is defined as the product of a storm's total kinetic energy per acre and its maximum 30 minute intensity (i.e. the rainfall erosion index) divided by 100. A storm's total kinetic energy per acre is calculated as follows. Using recording raingauge data, individual rainstorms are divided into portions of uniform intensity. For each intensity interval the kinetic energy per unit volume of rainfall (in foot-tons per acre-inch) is calculated according to (Wischmeier, 1959)

$$E = 916 + 331 \cdot (\log_{10} I) \qquad (2)$$

where I is the rainfall intensity espressed in inches per hour. Finally, the kinetic energy per unit volume of rainfall is multiplied by the amount of rain (in inches) that has fallen at that intensity interval, and the resultant increments of energy per acre summed to obtain the total kinetic energy per acre. It should be noted that an inconsistency in Wischmeier's widely quoted reoprt of 1959 could lead to confusion in using the above equation. In this report, he erroneously referred to the total kinetic energy per acre as having units of foot-tons per acre-inch. Of course, the correct units are foot-tons per acre.

In general, the best correlation between the rainfall factor and soil loss is obtained when: (1) rains separated by less than six hours are treated as a single storm, (2) storms of less than 0.5 inches of rain are ignored as insignificant, and (3) individual storm rainfall factors are summed, and compared to soil loss on an annual basis (Wischmeier, 1959). Recently it has been shown that where snowmelt runoff is important, annual values of the rainfall factor can be adjusted for this condition (McCool et al., 1976).

The soil erodibility factor, K, is the average erosion rate per unit of erosion index for a specific soil in continuous fallow on a 9 percent slope 72.6 feet long. Values of K were originally obtained by direct field measurement on a few agricultural soils in the central United States, and were estimated for other soils by comparison of their physical properties (Wischmeier and Smith, 1965). Today the soil erodibility factor is generally computed from a nomograph (Figure 1) developed by Wischmeier et al. (1971). Five soil parameters are used to predict erodibility: percent silt plus very fine sand, percent sand greater than 0.10 millimeters in diameter, organic matter content, structure, and saturated permeability.

It should be noted that the nomograph only considers organic matter levels between 0 and 4 percent. In general, organic matter levels above 4 percent are considered to have little or no additional effect on a soil's erodibility (Young, 1975). However, Wischmeier et al. (1971) state that "whether or how much soil erodibility declines further when organic matter levels exceed 4 percent has not been determined." Where a soil's erodibility changes along a slope, Wischmeier (1974) has provided a method for calculating an adjusted soil erodibility value.

The topographic factor, LS, is the ratio of soil lost from a slope of specified length and gradient to that of a 9 percent slope 72.6 feet long. The topographic factor is defined by Clyde et al. (1978) as

$$LS = (650+450s+65s^2)\cdot(b/72.6)^m/(10{,}000+s^2) \qquad (3)$$

where

s is the specified slope steepness in percent,

b is the specified slope length in feet, and

m is an exponent dependent upon slope steepness.

For slopes less than 0.5 percent, the suggested value of m is 0.3; for slopes from 0.51 to 10 percent, the suggested value of m is 0.5; and for slopes greater than 10 percent, the suggested value of m is 0.6. Since information has not been available to evaluate the LS factor on steep slopes, Wischmeier and Meyer (1973) caution that use of the equation on slopes greater than 20 percent is speculative.

Where necessary, a procedure for adjusting the LS factor for non-uniform slopes has been described by Wischmeier (1974). The procedure involves: (1) dividing the slope into two or more equal length segments of essentially uniform slope, (2) computing the LS factor for each segment, (3) multiplying the segment LS value by an adjustment factor, and (4) summing the adjusted LS values. The adjustment factor (af) is calculated by the equation

$$af = ((j)^{m+1} - (j-1)^{m+1})/n^m \tag{4}$$

where

j is the sequence number of the segment starting from the top of the slope,

m is the slope length exponent, and

n is the number of equal length segments. The above procedure assumes that there is no upslope deposition.

The cover and management factor, C, is the ratio of soil lost from a field with specified cover and management to that of a fallow field plowed up and down slope. Since C values must be determined by experimentation in plot studies, numerous tables and graphs have been developed to provide the USLE user with appropriate values (Wischmeier and Smith, 1965; Wischmeier and Meyer, 1973; Curtis et al., 1977; Evans and Kalkanis, 1977; Kimberlin and Moldenhauer, 1977; Mannering and Fenster, 1977; U.S. Soil Conservation Service, 1977; Clyde et al., 1978). Recently it has been reported (Wischmeier, 1975) that the value of the C factor is based on three distinct but interrelated effects: (1) the effect of the vegetative cover in direct contact with the soil surface, (2) the effect of canopy cover, and (3) the effect at and beneath the soil surface from past land management. For undisturbed lands, Wischmeier (1975) has developed a series of three graphs (Figure 2) for calculating the effect of each of these parameters. The product of the three parameters is then used as the C factor in the USLE.

The last factor in the USLE is the erosion control practice factor P. The P factor was developed specifically to account for the effect of contouring, strip-cropping, and terracing on farmlands. It is hypothesized that the effectiveness of terraces and other diversions which reduce the effective slope length and the concentration of runoff, will be similar on construction sites (Wischmeier and Meyer, 1973). Values of the P factor are available from the published literature (Wischmeier and Smith, 1965).

2.3.3 Sediment Delivery Ratios

It must be emphasized that all of the equations discussed above, including the USLE, only predict the amount of sediment moved from its original location on a slope. The equations do not account for sediment that may be deposited. In order to predict sediment yield, it is necessary to use a sediment delivery ratio in combination with an estimate of the soil eroded. The sediment delivery ratio is defined as the percentage of eroded soil that is delivered to a specified point. The ratio is developed from experimental data for a particular region and is related to a number of watershed characteristics including: area of the drainage basin, channel density of the watershed, ratio of watershed relief to maximum length, percent slope of buffer strip[1], and slope length of buffer strip (Manor, 1958; Manor, 1965; Mutchler, 1975; Curtis et al., 1977).

---

[1]An undisturbed area between a potential source of erosion and surface water.

CHAPTER 3: THE STUDY AREA

3.1 Climate

In order to consider the effects of forest (or land use) management on erosion, intensive study sites were established at the Moose Creek Embankment and the Caribou-Poker Creeks Research Watershed. Both locations are within the Tanana Basin.

The climate of the Tanana Basin is characterized as continental (Johnson and Hartman, 1969), with long cold winters and short warm summers. No long-term climatic data exist for either site. However, it is likely that the mean annual temperature is approximately 26°F, with a mean July temperature of 61°F and a mean January temperature of -12°F. The mean annual precipitation is probably 11 to 15 inches in the Caribou-Poker Creeks Research Watershed and approximately 10 to 12 inches at the Moose Creek Embankment. The cumulative rainfall at each of the sites during the study period is shown in Figure 3.

3.2 Caribou-Poker Creeks Research Watershed

The Caribou-Poker Creeks Research Watershed is located approximately 25 miles north of Fairbanks. It is representative of the forested hills at the lower elevations of the Yukon-Tanana Uplands. Five study plots were established in the watershed, from which soil erosion and related parameters could be monitored. Plots 1, 2, and 3 were located on a permafrost-free upland site, while plots 4 and 5 were located on a permafrost-dominated lowland site (Figure 4). A tipping bucket recording rain gauge was used to measure the quantity and intensity of rainfall.

3.2.1 The Upland Site

Each plot on the upland site is 15 feet wide by 50 feet long, and is bounded on three sides by a wooden border extending approximately 3 inches above and below the soil surface. The lower boundary of the plot is formed by a covered rain gutter set flush with the soil surface and draining into a covered 55-gallon drum. Data collection began late in the summer of 1977 on plots 1 and 3, and early in the spring of 1978 on plot 2.

Vegetation on plots 1, 2, and 3 has historically been that of a spruce-birch-aspen forest with an average effective canopy height of approximately 35 feet. Recently, however, the vegetation in the vicinity of plots 1 and 2 has been altered. The trees on plots 1 and 2 were felled in 1974 and removed in 1977. Also during the summer of 1977, the undergrowth on plot 1 was stripped from the site to expose mineral soil. In 1978 a tracked vehicle made approximately a dozen passes over plot 2 in order to disturb the dense ground cover. Thus, the condition of the plots at the start of the study was as follows. Plot 1, stripped of all vegetation, consisted of exposed rock fragments and mineral soil. Plot 2 contained a fairly dense cover of club moss and grass, while plot 3 was undisturbed. It consisted of a spurce-birch-aspen overstory with a thick layer of litter on the forest floor. Photographs of the plots are shown in Figures 5, 6, and 7.

The topography, aspect, and soils of the three plots are similar. Plots 1 and 2 have an 18 percent uniform slope, while plot 3 has a 17 percent uniform slope. All three plots have a south aspect.

Based on the work of Rieger et al. (1972), the soil on the upland plots is of the Olness soil series. It is typically a silt loam from 0 to 19 inches and a very gravelly silt loam from 19 to 40 inches. Furthermore, the soil exhibits a weak thin platy to weak fine subangular blocky structure.

Laboratory analysis indicates that the soil consists of 64 percent silt plus very fine sand and 25 percent sand greater than 0.1 millimeters in diameter (Figure 8). The bulk density of the soil, determined from 14 soil samples, averages 1.4 grams per cubic centimeter (standard deviation of 0.21 grams per cubic centimeter), and the organic content averages 7 percent (Table 1). Soil saturated permeability, determined from four soil samples, averages 0.14 inches per hour (standard deviation of 0.13 inches per hour), and based on U.S. Department of Agriculture (1951) criteria, is classed as slow.

3.2.2 The Lowland Site

Plots 4 and 5 are located on an abandoned trail in a permafrost-dominated section of the watershed. While each of the plots averages 9 feet wide, plot 4 is 50 feet long and plot 5 is 250 feet long. The sides of the plots are formed by the dense layer of sphagnum moss and black spruce surrounding the trail. A three-sided plywood container forms the lower boundary of each plot and collects the eroded soil.

The upper boundary of plot 4 is the plot 5 collection box, while the upper boundary of plot 5 consists of a water bar across the trail. A photograph of the plot 4 collection box, with the permafrost trail in the background, is shown in Figure 9.

The trail in which the plots are located was formed by running tracked vehicles across the tundra. Use of the trail consisted of approximately 10 passes per week during July and August of 1975, approximately four passes per week during the summer of 1976, and approximately one pass per week during the summer of 1977. Access was restricted and the plots established in the spring of 1978. Vegetative cover on both plots consisted of dead, churned-up sphagnum moss.

Although the average slope of both plots is 9 percent, plot 4 was raked to provide a uniform slope while plot 5 was left with an irregular slope and two pronounced ruts. Each rut is approximately 1.5 feet wide by 6 inches deep. The slope gradient of plot 5 for specific slope length intervals, starting from the collection box, is: 0 to 50 feet, 10 percent; 50 to 100 feet, 8 percent; 100 to 150 feet, 10 percent; 150 to 200 feet, 9 percent; and 200 to 250 feet, 7.5 percent. Both plots have a west aspect.

Based on the work of Rieger et al. (1972), the soil on the lowland plots is of the Saulich soil series. It is typically a silt from 0 to 3 inches and a silty permafrost from 3 to 12 inches. The soil structure is massive.

Laboratory analysis indicates that the soil consists of 65 percent silt plus very fine sand and 30 percent sand greater than 0.1 millimeters in diameter (Figure 10). The bulk density of the soil, determined from three soil samples, averages 1.0 gram per cubic centimeter (standard deviation of 0.21 grams per cubic centimeter), while the organic content averages 12.7 percent (Table 1). Soil saturated permeability, determined from three soil samples, averages 0.26 inches per hour (standard deviation of 0.29 inches per hour). Based on U.S. Department of Agriculture (1951) criteria, the saturated permeability is classed as moderately slow.

3.3 Moose Creek Embankment

The Moose Creek Embankment is located approximately 17 miles east of Fairbanks in the Chena River floodplain, and is adjacent to the Tanana River in the vicinity of the plots. Seven plots established in 1977 by the Cold Regions Research and Engineering Laboratory were utilized for this study. A tipping bucket recording rain gauge located approximately 2 miles north of the plots provided precipitation data.

The plots are located adjacent to each other on a flood control embankment being constructed by the Alaska District of the U.S. Army Corps of Engineers (Figure 11). Each plot is 4 feet wide and 50 feet long. While the sides of the plots are unbounded, the top of the embankment provides an upper boundary. A covered 30-gallon metal collection box, set flush with the soil surface, provides the lower boundary. The plots all have a uniform slope of 48 percent and an east aspect. Photographs of plots 37, 29, and 27 are exhibited in Figure 12.

The plots are situated on approximately 6 inches of topsoil covering a gravel embankment. The gravel embankment consists of fill material in which less than 4 percent is smaller than 0.075 millimeters and less than 40 percent is smaller than 0.425 millimeters (Gaskin and Johnson, 1978). The soil exhibits a fine granular structure, and consists of 45 percent silt plus very fine sand and 50 percent sand greater than 0.1 millimeters in diameter (Figure 13). Bulk density, determined from 51 soil samples, averages 1.3 grams per cubic centimeter (standard deviation of 0.12 grams per cubic centimeter), while the organic content averages 5.8 percent (Table 1). Soil saturated permeability, determined from three soil samples, averages 0.39 inches per hour (standard deviation of 0.6 inches per hour). Based on U.S. Department of Agriculture (1951) criteria, saturated permeability is classed as moderately slow.

Three vegetative erosion control treatments are represented by the seven plots (Gaskin and Johnson, 1978). Plot 37 was planted with a seed mixture consisting of 10 pounds per acre of ryegrass, 22 pounds per acre of red fescue, and 7 pounds per acre of nugget bluegrass. Plots 28, 29, and 30 were treated with the seed mixture described above, unrooted willow cuttings planted on a 1 yard square spacing, and 2.2 tons per acre of straw mulch. Plots 25, 26, and 27 were treated with unrooted willow cuttings planted on a 1 yard square spacing and 2.2 tons per acre of straw mulch.

All the plots were fertilized when established in 1977, and the right half of each plot was refertilized in 1978. By the end of the 1977 growing season, the plant growth on plots 25, 26, and 27 was similar in density to that on plots 28, 29, and 30. On plots 28 through 30, the type of vegetation was that of the planted seed, while on plots 25 through 27 the vegetation apparently developed from the seed of weeds present in the straw mulch at the time of harvesting.

CHAPTER 4: METHODS AND MATERIALS

4.1 Collection and Analysis of Eroded Soil and Runoff

Soil from each of the sediment traps was collected and analyzed at predetermined intervals. During the 1977 field season, after a plot was established at the Caribou-Poker Creeks Research Watershed, its sediment trap was observed weekly. At the Moose Creek Embankment, the plots were also checked on a weekly basis after the authors were given permission to use the plots in June of 1977. The sediment traps were emptied whenever sediment was found. During the 1978 field season, all sediment traps were emptied on a monthly basis. Sediment was collected by pumping the runoff from the sediment trap, obtaining a suspended sediment sample, and collecting the settled sediment from the bottom of the tank.

In the laboratory, both a 25 milliliter sample of the suspended sediment and the total quantity of settled sediment were dried to a constant weight at 103°C. The total sediment weight was then calculated by computing the dry weight of sediment in the total volume of runoff and adding to it, the dry weight of the settled sediment.

Weight lost on ignition was determined by taking samples previously dried at 103°C and then igniting the samples at 550°C. Suspended sediment samples were ignited for 15 minutes, while settled sediment samples were ignited for 30 minutes. The difference between the initial dry weight and the weight after ignition is the weight lost on ignition. Further details concerning the analysis of dry sediment weight and weight lost on ignition are presented in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association et al., 1976).

4.2 Percent Cover Analysis

Analysis of percent cover was accomplished by one of two methods. The first method, which was used to determine either percent ground cover or percent canopy cover, consisted of taking three 35 millimeter photographs of each study site (Figure 14). The developed picture was projected on a grid and the cover status at 100 randomly selected points was recorded. Both rock and vegetative cover were considered in determining the average percent ground cover. The second method, which was occasionally used to determine ground cover, involved laying a tape measure along the ground and determining the cover status at 100 predetermined intervals. Percent cover was estimated only once at each plot during the 1977 field season, while percent cover was estimated once a month during the 1978 field season.

4.3 Collection and Analysis of In Situ Soil Parameters

In general, the methods used for determining the bulk density, soil gradation, and saturated permeability followed standard practice. Soil bulk density was analyzed by the procedure of Blake (1965). Soil gradation was determined by dry sieving soil samples down to a maximum diameter of 0.053 millimeters, and using the hydrometer method to determine the particle gradation below 0.053 millimeters (Day, 1965). The saturated permeability of undisturbed soil cores was measured with a constant head permeameter as outlined by Klute (1965). All soil samples were collected from the upper 2.5 inches of the mineral soil profile.

The organic content of the soil was determined by a chemical oxidation procedure (Bremner and Jenkinson, 1960). The procedure used potassium dichromate to oxidize the organic carbon present in a 0.25 gram soil sample. Weight of organic matter was then estimated by assuming the organic mass to be 53 percent carbon by weight (Allison, 1965).

CHAPTER 5: MEASUREMENTS OF SHEET-RILL EROSION WITHIN INTERIOR ALASKA

5.1 Erosion Generated by Rainfall-Runoff

During the summers of 1977 and 1978, a number of sheet-rill erosion measurements were taken on research plots at two locations within interior Alaska. A discussion of the plots is available in Chapter 3, and a brief description of the plot treatments is presented in Table 2. Soil erosion data collected at the plots appear in Tables 3 and 4, while the cover data are presented in Tables 5 through 7. In order to obtain as much information as possible from the limited data, the measurements will be discussed in light of the research conducted by other investigators.

5.1.1 The Magnitude of Sheet-Rill Erosion

Sediment data collected on plot 3 indicates that the geologic rainfall erosion rate for the spruce-birch-aspen forests, of interior Alaska, is on the order of 0.01 tons per acre per year. Piest (1970) has suggested that the normal geologic erosion rate for vegetated areas is commonly less than 0.3 tons per acre per year. Since the value for plot 3 does not consider erosion from snowmelt, the two values are not strictly comparable. However, it is obvious that the measured rate is particularly low. This is probably due to the fact that the ground cover was thick, and rainfall within interior Alaska is low compared to areas of similar cover in the contiguous United States.

A comparison of the erosion data from plots 2 and 3 indicates that harvesting the trees, with only minor disturbance of the surface cover, did not substantially increase the erosion rate. Stripping all the vegetation from the soil surface, however, increased rainfall erosion 18 times above that produced on the forested plot. Thus, the increase in sediment yield often reported to be associated with timber harvesting is probably related to construction activities, rather than to timber harvesting per se.

It is also interesting to note that the rainfall erosion from plot 4, on the permafrost trail, was only 0.03 tons per acre per year. This was considerably less than was expected, considering the normal geologic erosion rate suggested by Piest (1970) and past investigations of erosion on tractor trails crossing permafrost (Hok, 1969; Rickard and Slaughter, 1973). The low quantity of eroded soil was apparently due to the low ice content of the permafrost, and a mostly intact organic mat. Bolstad (1971) has already noted that revegetation on permafrost trails can be accomplished easier than on some nonpermafrost trails. Therefore, it appears that erosion on permafrost trails need not be excessive, if steps are taken to locate the trails across permafrost with a low ice content, protect the organic mat, and revegetate trails when no longer needed.

Finally, an average of all the plot data indicated that the single largest storm produced 72 percent of the annual rainfall erosion (standard deviation of 20 percent). The mean ranged from 33 percent on plot 3 to 95 percent on plot 37. Thus, the fact that ground cover on a construction site will only be disturbed for a short period of time is no guarantee that substantial erosion will not occur.

5.1.2 Use of Seed, Mulch, and Willow Cuttings for Erosion Control

In order to determine the effectiveness of various combinations of seed, straw mulch and unrooted willow cuttings for controlling soil erosion, a number of plots were established at the Moose Creek Embankment. A discussion of the plots is available in Section 3.3, while a brief summary of the plot treatments is presented in Table 2. The soil eroded and the percent cover data are presented in Tables 4 and 7 respectively. Values of the mean soil eroded and the mean percent cover, for each of the replicates, are given in Tables 8 and 9.

It should be noted that vandalism on plots 30 and 37 during July of 1978 caused the sediment collected to differ from what it might have been without the disturbance. On plot 37 a motorcycle track across the plot, 2 inches deep and 5 inches wide, reduced the area draining into the sediment trap by approximately 40 percent. To account for this, the area of the plot was reduced accordingly when computing the sediment eroded per unit area. A motorcycle track through the center of plot 30, concentrated the runoff and substantially increased the amount of erosion. Since the plot was no longer representative of sheet-rill erosion on the grass-willow-straw mulch-fertilizer treatment, plot 30 was eliminated from calculations of the 1978 mean treatment parameters.

Data collected at the Moose Creek Embankment indicated that in the 2 years following site rehabilitation, use of a grass-willow-straw mulch-fertilizer treatment reduced mean annual rainfall erosion by 98 percent from that of a grass-fertilizer treatment. The use of a willow-straw mulch-fertilizer treatment reduced erosion by 95 percent. Both treatments reduced erosion slightly more in the first year than in the second year.

In order to determine if the annual quantity of soil eroded on the grass-willow-straw mulch-fertilizer treatment was significantly different from that on the willow-straw mulch-fertilizer treatment, the variances of the paired treatment means were compared using an F-test, and the differences between the means using a paired t-test (Sokal and Rohlf, 1969). At the 99 percent confidence level, the variances of the treatment means were similar, while the difference between the means was not significant. An analysis of the 1978 cover data also indicated that, at the 99 percent confidence level, the variances of the treatment means were similar while the difference between the means was not significant. Therefore, the effectiveness of the grass-willow-straw mulch-fertilizer treatment in controlling erosion was not significantly different from that of the willow-straw mulch-fertilizer treatment.

Thus, a number of interesting questions may be posed. Given a limited source of funds, would it be preferable to rehabilitate disturbed areas with a one-time application of grass, mulch, and fertilizer? Or should one use only locally grown straw mulch and fertilizer? In the later case, the balance of the funds would be used to refertilize the area in the second year. Further, are willow cuttings needed to obtain the reduction in erosion observed in this study? The answers to these questions are unclear.

However, observations made during the study provide some insight for future erosion control programs. The portion of each plot refertilized in 1978 appeared to produce substantially denser vegetation than the unfertilized portion. Furthermore, the unrooted willow cuttings did not seem to produce enough growth to influence erosion on the plots. Thus, it is hypothesised that the unrooted willow cuttings were in no way responsible for reducing erosion on the plots. It is also hypothesized that locally grown straw mulch used to control erosion, with applications of fertilizer in the first and second year, is superior to use of seed, mulch and fertilizer in a one-time application.

Finally, it is interesting to compare the amount of soil eroded from plot 30 with that from plots 28 and 29 (Table 3). A single track, down the center of this plot, apparently increased erosion on the plot by approximately 4 tons per acre or 1200 percent. Thus, a relatively minor change in surface cover, combined with a concentrating of runoff, produced a substantial increase in erosion. Furthermore, extensive efforts in erosion control were seriously undermined by uncontrolled vehicular traffic.

5.1.3 Organic Content of Eroded Soils

The organic content of eroded soil is of particular interest because it influences the oxygen and nutrient cycles of surface waters. An easily obtained indicator of soil organic content, which is often used, is weight lost on ignition. The percent weight lost on ignition from eroded soil at the Caribou-Poker Creeks Research Watershed and the Moose Creek Embankment is given in Tables 10 and 11.

To determine how closely the weight lost on ignition represented the weight of organic matter, a series of tests were performed. An analysis of four soil samples suggested that 0.11 percent of the weight lost on ignition (standard deviation of 0.02 percent) was due to loss of hygroscopic water rather than loss of organic matter. To determine if any organic matter remained after ignition, 38 previously ignited soil samples were chemically analyzed for organic content. The results indicated that there was approximately 1.5 times as much weight in organic matter as there was weight lost on ignition (standard deviation of 0.53). Thus, although the quantity of eroded organic matter can only be crudely estimated from the data in Tables 10 and 11, trends in the organic content of the eroded soil may be observed.

From the data in Tables 10 and 11, it appears that the percentage of organic matter in the eroded soil decreased with a decrease in surface cover. However, due to an increased erosion rate, the quantity of eroded organic matter increased as the amount of surface cover decreased. Therefore, while landscape manipulation clearly influenced the ratio of organics to inorganics in the eroded soil, it did not decrease the amount of organic material available to associated surface waters.

5.1.4 Error in Erosion Measurements Associated with Wind Blown Sediment

Although covers were placed on the sediment traps in an effort to prevent windblown material from settling in the basins, some material apparently did enter the traps. The amount of windblown soil collected during May of 1978, when no runoff had occured, is presented in Tables 3 and 4. No estimate of the amount of windblown soil collected by the traps is available for other months of the study. However, these values are presented to provide an indication of the magnitude of this potential source of error. In general, the amount of windblown soil collected during May of 1978 approaches the amount of sediment eroded from the smaller rainstorms.

5.1.5 Gradation of Eroded Soil

A number of investigators have suggested that the magnitude of erosion is inversely proportional to the amount of time following a surface disturbance (Leaf, 1974; Megahan, 1974). Megahan (1974) found that the decrease in erosion with time was not necessarily due to an increase in vegetative cover. Furthermore, he suggested that in such cases the decrease was due to surface armoring caused by differential erosion of the finer particles.

In order to determine if particles less than 2 millimeters in diameter were providing an armor surface, a soil gradation curve was produced for the sediment collected from plot 37 on August 30, 1978. It is presented in Figure 7. The curve, for all practical purposes, is identical to the in situ soil curve presented for this site in Figure 6. Hence, the surface composition of the soil did not change after 16 months of erosion. Any reduction in erosion with time, therefore, is probably not due to the formation of an erosion-resistant surface composed of particles less than 2 millimeters in diameter. From observations of the plots in this study, it is hypothesized that a decrease in erosion with time is primarily due to an increase in vegetative cover, and secondarily to armoring by rock fragments over 2 millimeters in diameter.

5.2 Erosion Associated with Snowmelt Runoff

5.2.1 Snowmelt Runoff Erosion Measurements

To estimate the amount of annual erosion associated with snowmelt runoff, plots 1 and 3 were operated during the spring of 1978. Snowmelt runoff on plot 1 started about April 10th and ended about May 1st, while runoff on plot 3 started and ended approximately a week later. The initial water equivalent of the snowpack at plot 1 was 2.9 inches.

For various reasons (i.e. the pit filled with runoff and floated the 55-gallon barrels, and the rain gutter frost heaved) neither all of the runoff nor sediment produced from the 1978 snowmelt was collected. However, on plot 1, 0.053 tons per acre of sediment (or 25 percent of the total quantity of sediment collected during 1978) was collected. On plot 3, 0.017 tons per acre of sediment (or 68 percent of the total quantity of sediment collected during 1978) was collected. Thus, although all of the 1978 snowmelt erosion was not collected, it is obvious that snowmelt runoff can contribute substantially to annual sheet-rill erosion within interior Alaska.

5.2.2 Extrapolation of the Snowmelt Runoff Data

Since the soil erosion data collected during the 1978 snowmelt was incomplete, an attempt was made to estimate the quantity of sediment that was actually eroded. In order to do this, two assumptions were necessary: (1) that 50 percent of the initial snowpack water equivalent left the site as surface runoff; and (2) that the average sediment concentration in the total runoff was equal to that in the runoff collected. The first assumption is based on the work of Erickson and McCorquodale (1966) working with the Manicouagan River basin in Quebec. They found that snowmelt runoff could be satisfactorily simulated by assuming that: (1) 8 percent of the initial snowpack water equivalent was lost to evaportranspiration in thinly forested and open areas, and (2) infiltration losses were constant at 0.057 inches per day during the melt period. Although the snow on plots 1 and 3 disappeared in 7 to 14 days, runoff occurred for approximately 3 weeks. Thus, using the above constants, it was estimated that approximately 50 percent of the initial snowpack water equivalent left plots 1 and 3 as surface runoff. Since suspended sediment samples were collected periodically throughout the snowmelt runoff, the second assumption was also considered reasonable.

Based on these assumptions, it is estimated that 40 percent of the annual erosion on the stripped plot occurred during snowmelt. It is also suggested that 90 percent of the annual erosion on the forested plot occurred during snowmelt. While both values are presented merely as estimates, they probably approximate the magnitude of erosion more accurately than do the measured values of 25 and 68 percent discussed in Section 5.2.1.

CHAPTER 6: USE OF THE UNIVERSAL SOIL EQUATION TO PREDICT SHEET-RILL EROSION WITHIN INTERIOR ALASKA

6.1 Predicting Sheet-Rill Erosion at the Caribou-Poker Creeks Research Watershed

The USLE has recently become popular with erosion control planners attempting to predict the quantity of soil eroded from a variety of landscape disturbances, and to choose between possible erosion control programs. Although the equation has proved useful in the contiguous United States, the environmental conditions within interior Alaska differ considerably from those where the equation was developed. Thus, in order to determine the accuracy of the USLE for predicting sheet-rill erosion within interior Alaska, data from the Caribou-Poker Creeks Research Watershed were used to test the equation.

A discussion of the USLE is presented in Chapter 2, and will not be repeated here. However, the mean 1978 values of each of the equation's parameters, as calculated according to the procedures described in Chapter 2, are presented in Table 12 and 13. The cover factor calculations (using Figure 2) assume that the root network was 100 percent intact on plot 1, 69 percent intact on plot 4, and 82 percent intact on plot 5. Although the individual storm values of the cover and management factor are not presented, they were calculated as described above using the data in Tables 5 and 6. The predicted soil loss compared to the measured soil loss, on an annual and an individual storm basis, is presented in Figures 16 and 17 respectively. From a review of Figures 16 and 17, a number of inferences can be made.

The ability of the USLE to predict soil loss was considerably better on an annual basis than it was on an individual storm basis. On an annual basis, the equation predicted an average of 21 percent more erosion than was actually measured (standard deviation of 34 percent). The range of the percent difference went from -13 percent on plot 1 to 66 percent on plot 3. This compared favorably with data presented by Piest (1970), in which 1,082 plot-years of data collected at seven locations, under various crop and management conditions, were compared to soil loss as predicted by the USLE. The data (Piest, 1970) indicated that, on the average, the USLE overestimated sheet-rill erosion by 26 percent.

As was mentioned in Chapter 2, the best results have been obtained when the USLE was used on an annual basis. However, with the increased interest in using the USLE, the temptation to use the equation for predicting erosion on an individual storm basis has grown. Thus, Figure 17 was produced in order to determine the magnitude of the error associated with using the USLE to predict erosion on an individual storm basis. On an individual storm basis, the USLE predicted an average of 174 percent more erosion than was actually measured (standard deviation of 328 percent). The range of the percent difference went from -65 percent on plot 3 to 1100 percent on plot 3.

A number of possible reasons exist for the variation between the predicted and measured values of sheet-rill erosion. It should be noted, however, that the sample size from which the above inferences of overestimation were made, represents only 5 plot-years of data.

The USLE was developed from approximately 10,000 plot-years of data (Wischmeier and Meyer, 1973). Assuming that the results of this study hold for a larger sample size, one reason for the overestimation may be associated with the quantity of organic matter present in the soil. As was mentioned in Chapter 2, increasing soil organic content from 0 to 4 percent decreases soil erosion. Increasing organic content above that, although generally assumed to have no additional effect, may actually continue to decrease erosion. It has also been suggested that the relationship used to describe the topographic factor may change (Wischmeier and Meyer, 1973; McCool et al., 1976), particularly as the slope steepness exceeds 20 percent.

6.2 The Rainfall Erosion Index as Measured at the Study Site

As described in Section 2.3.2, the rainfall erosion index is the product of a storm's total kinetic energy and the maximum 30 minute intensity. The erosion index for all storms involving 0.5 inches or more of rain is presented in Tables 13 and 14. The distribution of the rainfall erosion index is presented in Figure 18. In the Fairbanks vicinity, the average annual value of the rainfall erosion index is reported to be equal to 1600 foot-tons per acre times inches per hour (Clyde et al., 1978). Thus, it appears that the total rainfall erosivity was below normal during both years of this study.

Through an understanding of the annual distribution of erosive rains, erosion control planners can more adequately assess the need for a particular erosion control program. For the 2 years of data collected, only 1 percent of the annual rainfall erosion index occurred during May (standard deviation of 2 percent). Furthermore, 30 percent occurred during June (standard deviation of 39 percent), 12 percent occurred during July (standard deviation of 24 percent), 34 percent occurred during August (standard deviation of 45 percent), and 23 percent occurred during September (standard deviation of 23 percent). Thus, the least erosive rainfall generally occurred during the months of May and July. Using the rainfall erosion index distribution, an erosion control planner can determine the percentage of the annual erosion index likely to occur in any given month. This information, combined with a knowledge of the expected monthly percentage of surface disturbance, will allow the planner to more accurately predict sheet-rill erosion. It should be noted, however, that the distribution only considers rainfall erosion; within interior Alaska it will be necessary to consider snowmelt erosion as well.

6.3 Estimation of the Cover and Management Factor

The USLE has only recently been used to predict sheet-rill erosion from nonagricultural lands. Thus, the value of the cover and management factor has not been thoroughly studies in relation to many construction activities. Sediment data collected at the Moose Creek Embankment presented an opportunity to determine the cover and management factor for three types of vegetative erosion control. This was accomplished by using the sediment data to solve the equation for the C factor.

Values of the USLE parameters, as they relate to the Moose Creek Embankment, are given in the following tables: soil loss in Table 4; the rainfall factor in Table 14; and the soil, topographic, and cover factors in Table 15. A brief summary of the plot treatments is presented in Table 2, while a complete discussion of the plots is available in Section 3.3.

As may be noted from a comparison of Tables 4 and 12, each year a certain quantity of sediment was produced from storms too small to be considered as contributing to the rainfall factor. This was to be expected, and tends to compensate for other errors present when using the USLE to predict annual soil erosion. However, on August 28, 1977 and on July 30, 1978 extremely large quantities of soil were eroded from the plots, without a rainstorm of comparable magnitude being recorded. Discussions with construction personnel confirmed that the rains were localized and may not have occurred at the rain gauge. Therefore, the value of annual soil erosion used in computing the cover and management factor included all of the sediment eroded from the plots, each year, except for the two storms discussed above.

Cover and management factors were computed for both the 1977 and the 1978 field seasons. Thus, the cover and management factor for plot 37 was 0.02 in 1977, while the C factor for plots 28 through 30 averaged 0.0020 (standard deviation of 0.0000). The C factor for plots 25 through 27, in 1977, averaged 0.0023 (standard deviation of 0.0015). For the 1978 field season, the C factor for plot 37 was 0.06 and the average C factor for plots 28 and 29 was 0.0028 (standard deviation of 0.0031). The 1978 C factor for plots 25 through 27 averaged 0.0047 (standard deviation of 0.0046). It was assumed that the value of the C factor was due, not only to the vegetative treatment (i.e. application of seed, mulch, etc.), but also to soil looseness from hauling topsoil onto the site.

In order to obtain a C factor that reflected just the vegetative treatment, it was necessary to eliminate the effect of soil looseness. Clyde et al. (1978) reported that loose soil to 12 inches, left rough, has a C factor of 0.8. Thus, by dividing each of the calculated C factors by 0.8, it was possible to estimate the C factor for the vegetative treatment alone. The computation yields a C factor equal to 0.03 for the seed-fertilizer treatment during 1977 and 0.07 for the treatment during 1978. For the seed-straw mulch-willow-fertilizer treatment, the average C factor becomes 0.0027 in 1977 and 0.0030 in 1978. The straw-mulch-willow-fertilizer treatment yielded an average C value of 0.0027 in 1977 and 0.0053 in 1978. As discussed in Section 5.1.2, it is assumed that the unrooted willow cuttings did not reduce soil erosion. Therefore, the C factors reported above only reflect the effect of the grass, straw mulch, and fertilizer.

These values are of particular interest when compared with the values suggested in the literature. Clyde et al. (1978) reported that C values for the above conditions are as follows: 0.64 for fresh seed plus fertilizer, 0.54 for seed plus fertilizer after 6 months, 0.38 for seed plus fertilizer after 12 months, and 0.01 for straw mulch. In almost every instance, the values calculated for the Moose Creek Embankment data are substantially less than those reported by Clyde et al. In the case of the straw mulch treatments, this can largely be explained by noting that both treatments produced a similar density of live vegetative cover. Specifically, plots 28 through 30 produced a vegetative cover from the planted seed, while plots 25 through 27 produced a cover of weeds, apparently from seed in the mulch itself.

If the C factor for seed is multiplied by the C factor for mulch (Clyde et al., 1978) to produce a seed plus mulch factor, a value more closely approximating the values calculated for the plot data is obtained. Thus, where locally grown straw mulch and fertilizer are used to control erosion, the C factor will be similar to that for seed, nonviable straw mulch, and fertilizer. When combining erosion control treatments for which a number of individual C values exist, it appears that the C value of the treatment is equal to the product of the individual C values.

It should be noted that Clyde et al. (1978) suggest that the value of the C factor decreases as the seed becomes established, while the plot data seems to suggest the opposite. The reason for this discrepency may involve the type of seed or the climatic conditions.

It should also be noted that because only half of each plot was refertilized in 1978, it is impossible to state the exact conditions governing the 1978 C factor values. Specifically, do the 1978 values represent treatments refertilized in the second year or treatments left unfertilized? The values are presented, therefore, only as a conservative estimate of the effect of refertilization in the year following the initial treatment. In general, it is possible that the C values calculated were less than those reported by Clyde et al. due to an overestimation of the K and LS factors, for reasons discussed in Section 2.3.2.

CHAPTER 7: EROSION AT TIMBER HARVESTING SITES ALONG THE PARKS HIGHWAY

It appeared that timber cutting itself created only very minor erosion, but that skid trails and roads exhibited signs of moderate to severe erosion when left unattended over a period of time (as short as a year, in one instance). In general, little damage other than site degradation (sometimes causing roads or skid trails to become impassible) had been done by the erosion, since the logging in this area is normally not in the vicinity of clear-water streams. However, sediment was observed as far as a quarter mile from a disturbed area (Fox, 1978), indicating the potential for sediment to travel a significant distance from the site. Where water bars were used in skid trails, and culverts with inside ditching were used in main haul roads, erosion appeared to be minor even though the water bars and culverts were apparently placed with no particular spacing requirements in mind. Thus, it appeared that with only a minimum of effort, the major portion of erosion associated with the timber harvesting activities observed could be controlled.

Finally, data collected at timber harvesting activities along the Parks Highway, west of Fairbanks, made another estimate of the cover and management factor possible. Using the nomographs presented in Figure 2 and the cover data presented in Table 16, it is suggested that the C factor varies as follows. In areas where the trees have been harvested with little or no damage to the soil surface, the C factor is about 0.002. For skid trails, where 3 to 15 percent of the ground cover has been disturbed, a value of approximately 0.004 to 0.009 is suggested. A value of 1.2 to 1.3 is suggested for haul roads, based on values suggested by Clyde et al. (1978) for compacted bulldozer scraped areas. For logging decks, a value between 0.04 (as calculated for plot 1 during 1977) and 1.3 is suggested, while for undisturbed spruce-birch-aspen Interior forests, a value of 0.002 is suggested. The above values are presented only to offer the erosion control planner an estimate of the magnitude of the cover and management factor.

CHAPTER 8: SUMMARY

A review of the mechanics of soil erosion suggests some basic principles that influence the success of an erosion control program. Specifically, since soil erosion is limited by either soil detachment or transport, erosion control programs that recognize and control the limiting parameter will be the most effective. Where it is necessary for forest harvesting activities to reshape the landscape, a reduction in the transport capacity can be achieved by using concave rather than uniform slopes. Where the organic content of the subsoil is less than that of the surface soil, the soil detachment capacity can be limited simply by preventing the exposure of subsurface soil. Using mulches or establishing a vegetative cover limits both the detachment and transport capacity of the rainfall and runoff.

In studying the magnitude of sheet-rill erosion within interior Alaska, the geologic rainfall erosion rate for spruce-birch-aspen forests was determined to be about 0.01 tons per acre per year. While harvesting the trees had little effect on the erosion rate, stripping all of the vegetative cover from the site produced 18 times as much erosion. Hence, the increase in sediment yield often associated with timber harvesting is probably related to construction activities which expose substantial quantities of mineral soil, rather than to timber harvesting per se. An average of all the rainfall erosion data collected in this study indicated that, in general, 72 percent of the annual rainfall erosion occured in a single storm.

Measurements of sheet-rill erosion on a permafrost trail indicated that only 0.03 tons per acre per year were eroded during the 1978 field season. This was considerably less than was expected from a review of the literature. Hence, erosion need not be extensive in permafrost trails if care is taken to locate the trails across permafrost with a low ice content, maintain surface cover, and prevent a concentration of surface runoff.

In erosion control work, use of a grass-willow-straw mulch-fertilizer treatment reduced mean annual rainfall erosion by 98 percent from that of a grass-fertilizer treatment. Use of a willow-straw mulch-fertilizer treatment reduced erosion by 95 percent. An analysis of the treatment means and variances, however, indicated that adding the seed mixture to the locally grown straw mulch did not significantly reduce erosion. Furthermore, it was hypothesized that the unrooted willow cuttings did not contribute to a reduction in soil erosion and that an application of straw mulch, fertilized in both the first and second year, might be the most practical treatment. As demonstrated by the erosion on a single motorcycle track, the benefits gained by an erosion control treatment can be largely negated by uncontrolled off-road vehicular traffic.

Analysis of the organic content in eroded soil indicated that, while the proportion of organic matter decreased after surface cover disturbance, the actual weight of eroded organic matter increased. Thus, landscape manipulation influenced the ratio of organics to inorganics in the eroded soil, but it did not decrease the amount of organic material available to associated surface waters.

Although it was impossible to determine a definite erosion rate associated with snowmelt runoff, enough information was obtained during 1978 to determine that snowmelt erosion is important. Through an analysis of the incomplete snowmelt erosion data, it was hypothesised that 90 percent of the annual erosion on the forested plot occurred during snowmelt runoff. It was further suggested that 40 percent of the annual erosion from a plot stripped of all vegetative cover occurred during snowmelt runoff.

From a one-year study on five plots, the Universal Soil Loss Equation was found to overestimate the annual rainfall erosion by an average of 21 percent. It was found to overestimate individual rainstorm erosion by an average of 174 percent. Thus, the accuracy of the equation, when used within interior Alaska, was similar to that reported for annual estimates of erosion in the contiguous United States.

Finally, a number of cover and management factor values were suggested for specific construction and forest management activities. For construction, the following values of the C factor were suggested: (1) 0.03 for the first year after grass seed is planted and fertilized; (2) 0.0027 for the first year after locally grown straw mulch is applied and fertilized; and (3) 0.0027 for the first year after grass seed is planted, and nonviable straw mulch and fertilizer are applied. The following values of the C factor were suggested for forest management activities: (1) 0.002 for undisturbed spruce-birch-aspen interior Alaska forests; (2) 0.002 for areas where the trees have been harvested with little or no damage to the surface cover; (3) between 0.004 and and 0.009 where 3 to 15 percent of the ground cover has been disturbed, such as on skid trails; (4) between 0.04 and 1.3 for logging decks, depending on the amount of soil compaction; and (5) between 1.2 and 1.3 for haul roads.

CHAPTER 9: FUTURE RESEARCH NEEDS

This study offers the erosion control planner an indication of the magnitude of erosion associated with landscape manipulation within interior Alaska. Further, it demonstrates the usefulness of the Universal Soil Loss Equation in assessing the need for, and the effectiveness of, erosion control programs. However, additional research is needed to develop a sound basis for erosion control requirements and to develop the most cost-effective programs.

The USLE only considers the amount of material eroded and does not account for material deposited. Thus, a method of estimating sediment yield should be developed. This is particularly important in order to develop a rational method for determining the width of buffer strip required between landscape disturbances and surface water. Traditionally, estimating sediment yield has been accomplished with sediment delivery ratios and gross estimates of erosion. Another approach involves the development of a quantitative model to estimate the quantity of material trapped by a buffer strip of a specified width, gradient, and vegetation. The combination of the USLE and such a model would allow the necessary width of buffer strip to be determined on a case-by-case basis. Unfortunately, the required width of buffer strip is often determined by the political climate.

As determined in this study, snowmelt runoff may represent between 40 and 90 percent of the annual sheet-rill erosion within interior Alaska. Hence, modification of the USLE rainfall factor to include snowmelt erosion would expand the versatility of the USLE considerably.

One approach to such a modification has already been outlined by McCool et al. (1976), working in eastern Washington. Initial research might begin by simply using plot studies to determine the suitability of this modification.

To increase the usefulness of the USLE for erosion control planners, it would also be desirable to develop a set of rainfall factor values based on specific return periods. Obviously, it would be completely unsatisfactory to design an erosion control program for merely the mean annual erosion. By designing an erosion control program for a storm of a given frequency of occurrence, an acceptable probability of failure could be determined in advance according to project requirements.

Further research might also attempt to replace the rainfall factor with a runoff factor. Since runoff is more directly related to erosion, such a modification might allow more accurate prediction of the erosion associated with individual rainstorms. A modification of this nature would probably be based on a combination of the peak and total runoff from a storm.

As noted in Section 2.3.2, soil containing more than 4 percent organic matter was not considered in the development of the nomograph (Wischmeier et al., 1971) for determining the soil erodibility factor. Due to the markedly different climatic conditions of interior Alaska, however, a large number of the surface soils are expected to contain more than 4 percent organic matter. For this reason, more research into the effects of organic matter levels above 4 percent on sheet-rill ersion is required.

As was also mentioned in Section 2.3.2, the topographic factor has not been studied intensively on slopes above 20 percent. This is undoubtedly due to its past use being primarily on agricultural lands. However, with the increased demand for an equation of this nature, it is necessary to validate and/or modify the relationship currently used to define the topographic effect. Analysis of the topographic factor is particularly important since, as was mentioned in Section 2.2.3, it accounts for one of the largest variations in soil erosion.

Development of cover and management factors for construction activities would be particularly well suited to a joint study with an analysis of the methods of vegetative erosion control applicable to interior Alaska. Considering the potential for future development within the Interior, a study of the type outlined above would provide a timely contribution to erosion control practice.

Although the list of research needs may seem overwhelming to the casual observer, a well-designed program to study surface erosion could answer many of the questions simultaneously. For instance, the effect of buffer strips, the topographic factor, the rainfall factor, snowmelt runoff, and the cover and management factor could all be studied simultaneously on large research plots of the type used in this study. However, such a study is not for the faint of heart. A sincere commitment to 5 or more years of studying the problem will be required to answer the questions posed above. It was only after a similar effort that the USLE was originally developed for agricultural lands.

LITERATURE CITED

Alaska Department of Environmental Conservation. 1977. Timber harvesting/water quality, problem description, draft for review. 208 Program, State of Alaska. 143 pp.

Allison, L.E. 1965. Organic Carbon. Pages 13671378 in C.A. Black, ed. Methods of soil analysis, Part 2. American Society of Agronomy, Inc., Madison, WI.

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1976. Standard methods for the examination of water and wastewater, 14th edition. American Public Health Association, Washington, DC. 1193 pp.

Balci, A.N. 1968. Soil erosion in relation to properties of eastern and western Washington. Soil Science Society of America Proceedings. 32(3): 430432.

Blake, G.R. 1965. Bulk density. Pages 374390 in C.A. Black, ed. Methods of soil analysis, Part 1. American Society of Agronomy, Inc., Madison, WI.

Bolstad, R. 1971. Catline rehabilitation and restoration. Pages 107116 in C.W. Slaughter, R.J. Barney, and G.M. Hansen, eds. Fire in the northern environment a symposium. Proceedings of a Symposium, University of Alaska, Fairbanks. Alaska Forest Fire Council and Alaska Section, Society of American Foresters.

Bremner, J.M., and D.S. Jenkinson. 1960. Oxidation by dichromate of organic matter in the soil and plant materials. Journal of Soil Science. 11(2): 394402.

Clyde, C.G., C.E. Israelsen, P.E. Packer, E.E. Farmer, J.E. Fletcher, E.K. Israelsen, F.W. Haws, N.V. Rao, and J. Hansen. 1978. Manual of erosion control principles and practices during high way construction. Utah Water Research Laboratory, Utah State University, Logan, Utah. Hydraulics and Hydrology Series UWRL/H78/02. 23 pp.

Cruse, R.M., and W.E. Larson. 1977. Effect of soil shear strength on soil detachment due to raindrop impact. Soil Science Society of America Journal. 41(4): 777781.

Curtis, N.M., A.G. Darrach, and W.J. Sauerwein. 1977. Estimating sheetrill erosion and sediment yield on disturbed western forest and woodlands. West Technical Service Center, U.S. Soil Conservation Service, Portland, OR. Woodland 10. 33 pp.

Day, P.R. 1965. Particle fractionation and particlesize analysis. Pages 545567 in C.A. Black, ed. Methods of soil analysis, Part 1. American Society of Agronomy, Inc., Madison, WI.

Dohrenwend, R.E. 1977. Raindrop erosion in the forest. Ford Forestry Center, Michigan Technical University, L'Anse, MI. Research Note 24. 19 pp.

Ellison, W.D. 1945. Some effects of raindrops and surfaceflow on soil erosion and infiltration. Transactions of the American Geophysical Union. 26(3): 415429.

Erickson, O.M., and J.A. McCorquodale. 1966. Application of computers to the determination of snowmelt runoff. Presented at Symposium 5 Statistical Methods in Hydrology, Montreal, Quebec. National

Evans, W.R., and G. Kalkanis. 1977. Use of the Universal Soil Loss Equation in California. Pages 3140 in G.R. Foster, ed. Soil erosion: prediction and control. Proceedings of a National Conference on Soil Erosion, Purdue University, West Lafayette, IN., 1976. Soil Conservation Society of America. Special Publication 21.

Foster, R.L., and G.L. Martin. 1969. Effects of unit weight and slope on erosion. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers. 95(IR4): 551561.

Foster, G.R., and L.D. Meyer. 1977. Soil erosion and sedimentation by water an overview. Pages 113 in Soil erosion and sedimentation. Proceedings of National Symposium on Soil Erosion and Sedimentation by Water, Chicago, IL. American Society of Agricultural Engineers.

Foster, G.R., and W.H. Wischmeier. 1974. Evaluating irregular slopes for soil loss prediction. Transactions of the American Society of Agricultural Engineers. 17(2): 305309.

Fox, J. D. 1978. Personal Communication, Institute of Water Resources, University of Alaska, Fairbanks, Alaska.

Fredericksen, R.L. 1965. Sedimentation after logging road construction in a small western Oregon watershed. Pages 5659 in Proceedings of the Federal InterAgency Sedimentation Conference, Jackson, MS., 1963. U.S. Agricultural Research Service. Miscellaneous Publication 970.

Gaskin, D., and L. Johnson. 1978. Draft preliminary results of the Chena Lakes Embankment revegetation project. Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers, Hanover, NW. Prepared for Corps of Engineers, Alaska District. 48 pp.

Heinemann, H.G., and R.F. Piest. 1975. Soil erosion sediment yield research in progress. Transactions of the American Geophysical Union. 56(3): 149159.

Hok, J.R. 1969. A reconnaissance of tractor trails and related phenomena on the north slope of Alaska. Bureau of Land Management, U.S. Department of Interior, Washington, DC. 66 pp.

Johnson, P.R., and C.W. Hartman. 1969. Environmental atlas of Alaska. Institute of Water Resources, University of Alaska, College. 111 pp.

Kimberlin, L.W., and W.C. Moldenhauer. 1977. Predicting soil erosion. Pages 3142 in Soil erosion and sedimentation. Proceedings of National Symposium on Soil Erosion and Sedimentation by Water, Chicago, IL. American Society of Agricultural Engineers.

Klute, A. 1965. Laboratory measurement of hydraulic conductivity of saturated soil. Pages 210221 in C.A. Black, ed. Methods of soil analysis, Part 1. American Society of Agronomy, Inc., Madison, WI.

Leaf, C.F. 1974. A model for predicting erosion and sediment yield from secondary forest road construction. Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins, CO. Research Note RM274. 4 pp.

Lusby, G.C. 1965. Causes of variations in runoff and sediment yield from small drainage basins in western Colorado. Pages 9498 in Proceedings of the Federal InterAgency Sedimentation Conference, Jackson, MS., 1963. U.S. Agricultural Research Service. Miscellaneous Publication 970.

Mannering, J.V., and C.R. Fenster. 1977. Vegetative water erosion control for agricultural areas. Pages 91106 in Soil erosion and sedimentation. Proceedings of National Symposium on Soil Erosion and Sedimentation by Water, Chicago, IL. American Society of Agricultural Engineers.

Manor, S.B. 1958. Factors affecting sediment delivery ratios in the Red Hills physiographic area. Transactions of the American Geophysical Union. 39(4): 669675.

Manor, S.B. 1965. Geology in sediment delivery ratios. Pages 108-110 in Proceedings of the Federal InterAgency Sedimentation Conference, Jackson, MS., 1963. U.S. Agricultural Research Service. Miscellaneous Publication 970.

Mansue, L.J., and P.W. Anderson. 1974. Effects of land use and retention practices on sediment yields in the Stony Brook basin, New Jersey. U.S. Geological Survey, Washington, DC. Water Supply Paper 1798L. 33 pp.

McCool, D.K., R.I. Papendick, and F.L. Brooks. 1976. The Universal Soil Loss Equation as adapted to the Pacific Northwest. Pages 2-135 to 2-147 in Proceedings of the 3rd Federal Inter-Agency Sedimentation Conference, Denver, CO. U.S. Water Resources Council. SEDCOM-03.

Meeuwig, R.O. 1969. Infiltration and soil erosion on Coolwater Ridge, Idaho. Intermountain Forest and Range Experiment Station, U.S. Forest Service, UT. Research Note INT-103. 5 pp.

_____. 1970. Sheet erosion on Intermountain summer ranges. Intermountain Forest and Range Experiment Station, U.S. Forest Service, Ogden, UT. Research Paper INT-85. 25 pp.

_____. 1971. Soil stability on high-elevation rangeland in the Intermountain area. Intermountain Forest and Range Experiment Station, U.S. Forest Service, Ogden, UT. Research Paper INT-94.

Megahan, W.F. 1974. Erosion over time on severely disturbed grantic soils: a model. Intermountain Forest and Range Experiment Station, U.S. Forest Service, Ogden, UT. Research Paper INT-156. 14 pp.

_____. 1975. Sedimentation in relation to logging activities in the mountains of central Idaho. Pages 74-82 in Present and prospective technology for predicting sediment yields and sources. Proceedings of the Sediment-Yield Workshop, U.S. Department of Agricluture Sedimentation Laboratory, Oxford, MS., 1972. U.S. Agricultural Research Service. ARS-S-40.

Meyer, L.D. 1971. Soil erosion by water on upland areas. Pages 27-1 to 27-25 in H.W. Shen, ed. River mechanics, Vol. 2. H.W. Shen, Fort Collins, CO.

Meyer, L.D., and L.A. Kramer. 1968. Relation between land-slope shape and soil erosion. Paper for presentation at the 1968 Winter Meeting of the American Society of Agricultural Engineers, Chicago, IL. Paper 68-749. 13 pp.

Meyer, L.D., D.D. DeCoursey, and M.J.M. Romkens. 1976. Soil erosion concepts and misconceptions. Pages 2-1 to 2-12 in Proceedings of 3rd Federal Inter-Agency Sedimentation Conference, Denver, CO. U.S. Water Resources Council. SEDCOM-03.

Meyer, L.D., G.R. Foster, and J.M. Romkens. 1975. Sources of soil eroded by water from upland slopes. Pages 177-189 in Present and prospective technology for predicting sediment yields and sources. Proceedings of the Sediment-Yield Workshop, U.S. Department of Agriculture Sedimentation Laboratory, Oxford, MS., 1972. U.S. Agricultural Research Service. ARS-S-40.

Musgrave, G.W. 1947. The quantitative evaluation of factors in water erosion - a first approximation. Journal of Soil and Water Conservation. 2(3): 133-138.

Mutchler, C.K. 1975. Effect of land use on sediment delivery ratios. Pages 1-11 to 1-21 in Proceedings of the 3rd Federal Inter-Agency Sedimentation Conference, Denver, CO. U.S. Water Resources Council. SEDCOM-03.

Mutchler, C.K., and R.A. Young. 1975. Soil detachment by raindrops. Pages 113-117 in Present and prosepctive technology for predicting sediment yields and sources. Proceedings of the Sediment-Yield Workshop, U.S. Department of Agriculture Sedimantation Laboratory, Oxford, MS., 1972. U.S. Agricultural Research Service. ARS-S-40.

Piest, R.F. 1970. Sediment sources and sediment yields. Journal of the Hydraulic Division, American Society of Civil Engineers. 96(HY6): 1283-1329.

Rickard, W.E., and C.W. Slaughter. 1973. Thaw and erosion on vehicular trails in permafrost landscapes. Journal of Soil and Water Conservation. 28(6): 263-266.

Rieger, S., C.E. Furbush, D.B. Schoephorster, H. Summerfield Jr., and L.C. Geiger. 1972. Soils of the Caribou-Poker Creeks Research Watershed, interior Alaska. Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers, Hanover, NH. Technical Report 236. 11 pp.

Singer, M. J., J. Blackard, E. Gillogley, and K. Arulanandan. 1978. Engineering and pedological properties of soils as they affect soil erodibility. California Water Resources Center, University of California, Davis. Contribution 166. 32 pp.

Sokal, R. R., and J. Rohlf. 1969. Biometry. W.H. Freeman and Company, San Francisco, CA. 776 pp.

U.S. Department of Agriculture, Bureau of Plant Industry, Soils, and Agricultural Engineering. 1951. Soil Survey Manual. Washington, D.C. Agricultural Handbook 18. 503 pp.

U.S. Soil Conservation Service. 1977. Procedure for computing sheet and rill erosion on project areas. Technical Relase 51 (Revision 2). 17 pp.

Wischmeier, W.H. 1959. A rainfall erosion index for a universal soil loss equation. Soil Science Society of America Proceedings. 23(3): 246-249.

_____. 1974. New developments in estimating water erosion. Pages 186-197 in Land use: persuasion or regulation. Proceedings of the 29th Annual Meeting of the Soil Conservation Society of American, Syracuse, N.Y.

_____. 1975. Estimating the soil loss equation's cover and management factor for undisturbed areas. Pages 118-124 in Present and prospective technology for predicting sediment yields and sources. Proceedings of the Sediment-Yield Workshop, U.S. Department of Agriculture Sedimentation Laboratory, Oxford, MS., 1972. U.S. Agricultural Research Service. ARS-S-40.

Wischmeier, W.H., and J.V. Mannering. 1969. Relation of soil properties to its erodibility. Soil Science Society of America Proceedings. 33(1): 131-137.

Wischmeier, W.H., and L.D. Meyer. 1973. Soil erodibility on construction areas. Pages 20-29 in Soil erosion: causes and mechanisms; prevention and control. Highway Research Board, National Research Council, Washington, D.C. Special Report 135.

Wischmeier, W.H., and D.D. Smith. 1965. Predicting rainfall-erosion losses from croplands east of the Rocky Mountains. Agricultural Research Service, U.S. Department of Agriculture, Washington, DC. Agricultural Handbook 282. 47 pp.

Wischmeier, W.H., C.B. Johnson, and B.V. Cross. 1971. A soil erodibility nomograph for farmland and construction sites. Journal of Soil and Water Conservation. 26(5): 189-193.

Wooldridge, D.D. 1963. Soil properties related to erosion of wildland soils in central Washington. Pages 141-152 in Forest-soil relationships in North America. Proceedings of the 2nd North American Forest Soils Conference, Corvallis, OR. Oregon State University.

Young, K.K. 1975. Erosion potential of soils. Pages 1-1 to 1-10 in Proceedings of the 3rd Federal Inter-Agency Sedimentation Conference, Denver, CO. U.S. Water Resources Council. SEDCOM-03.

Young, R.A., and C.K. Mutchler. 1969. Effects of slope shape on erosion and runoff. Transactions of the American Society of Agricultural Engineers. 12(2): 231-233, 239.

Zingg, A.W. 1940. Degree and length of land slope as it effects soil loss in runoff. Agricultural Engineering. 21(2): 59-64.

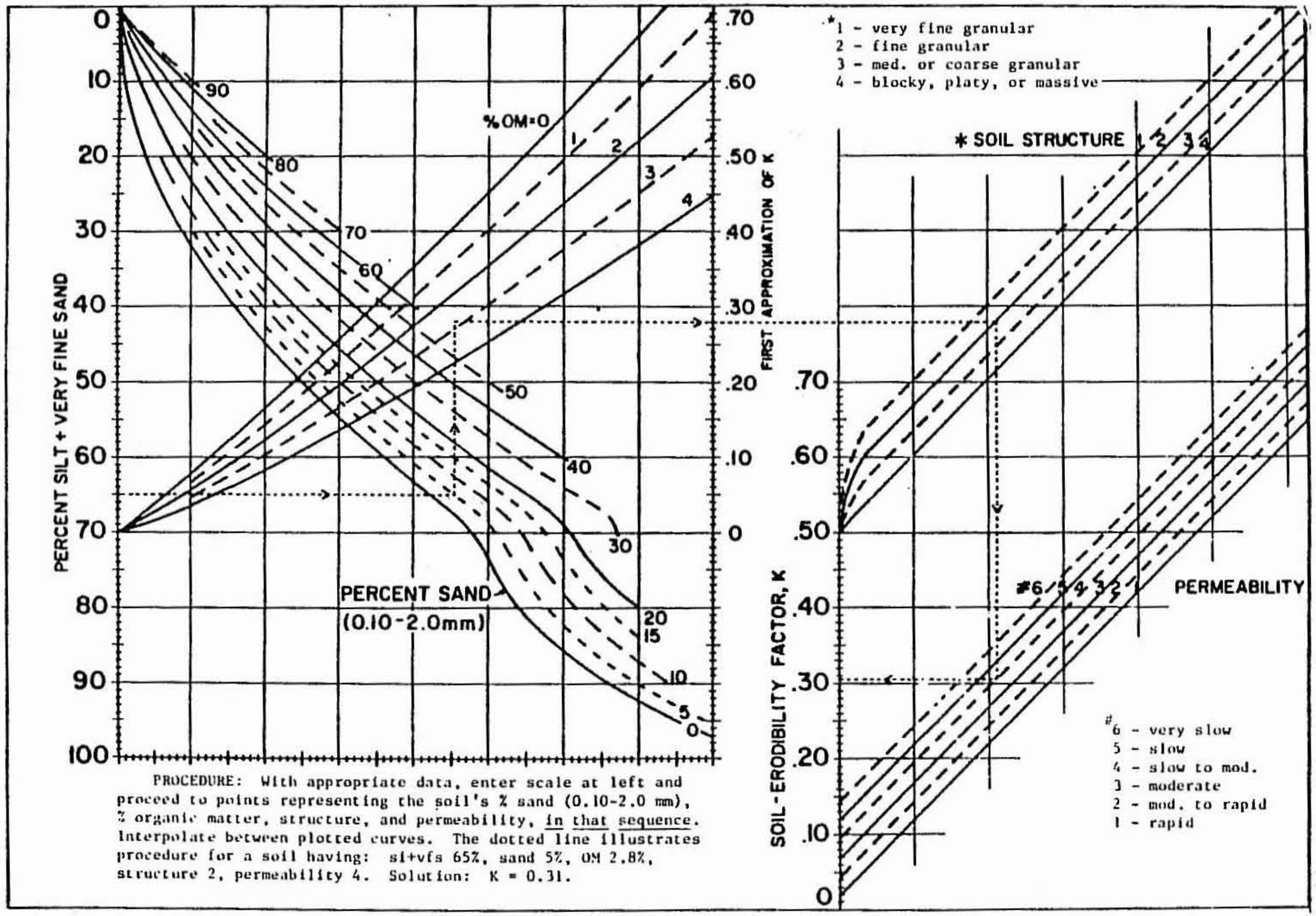
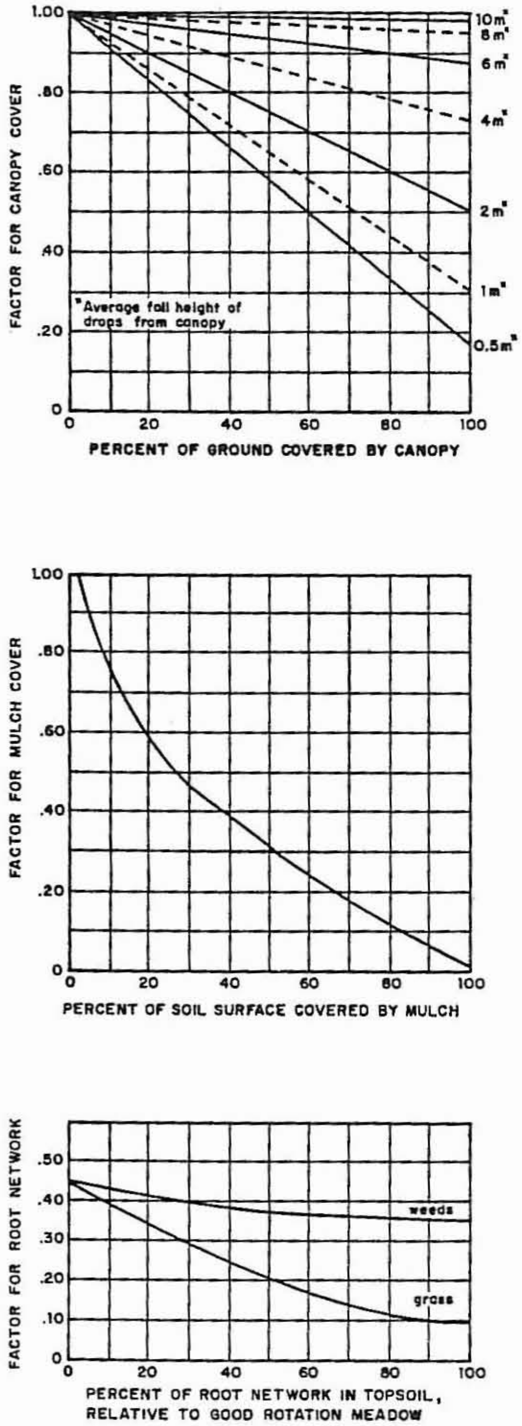


Figure 1: Nomograph for determining the soil erodibility factor K in tons per acre per increment of rainfall erosion-index (After Wischmeier et al., 1971).



Procedure: Enter figures at left with percent of ground covered by canopy, percent of soil surface covered by mulch, and percent of root network in topsoil relative to good meadow; obtain factors for canopy cover, mulch cover, and root network. The canopy factor is then multiplied by the percent of bare ground and the product subtracted from one. Finally, the above value is multiplied by the factors for mulch effect and root network, yielding the C factor.

Figure 2: Nomographs for determining the dimensionless cover and management factor C (After Wischmeier, 1975).

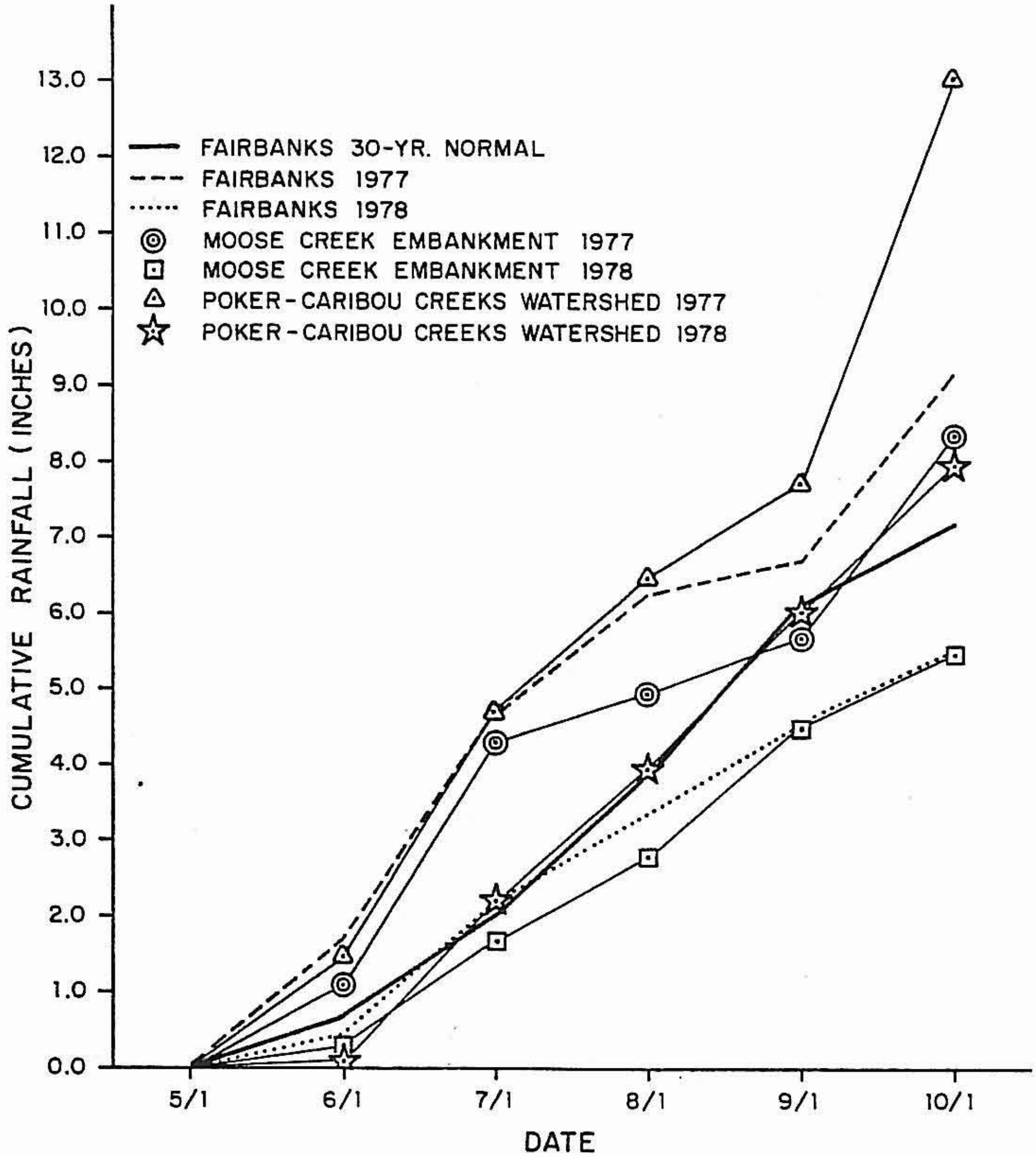


Figure 3: Cumulative Rainfall.

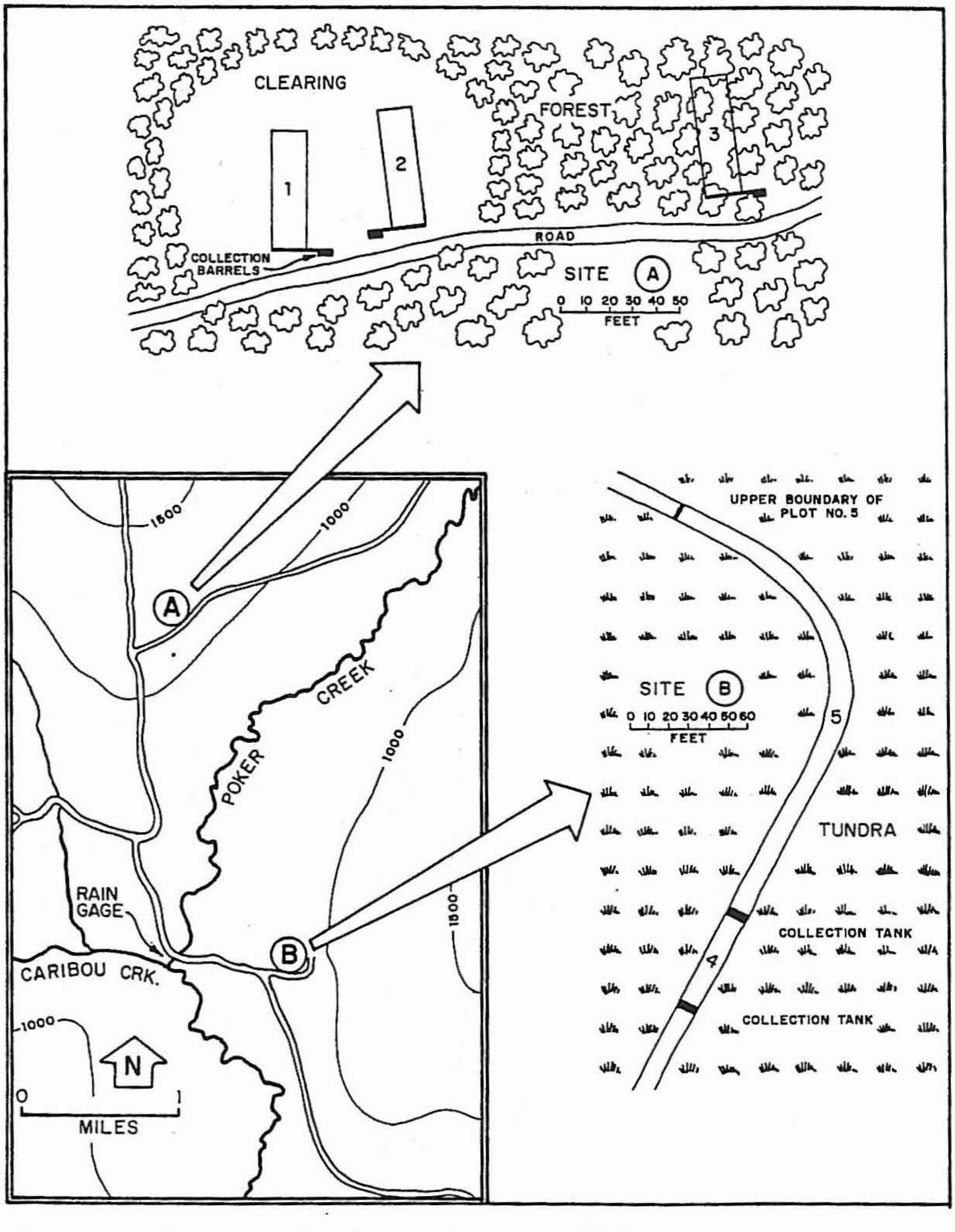


Figure 4: Plan of study site at the Caribou-Poker Creeks Research Watershed.

Figure 5: Plot 1 at the Caribou-Poker Creeks Research Watershed.

Figure 6: Plot 2 at the Caribou-Poker Creeks Research Watershed.

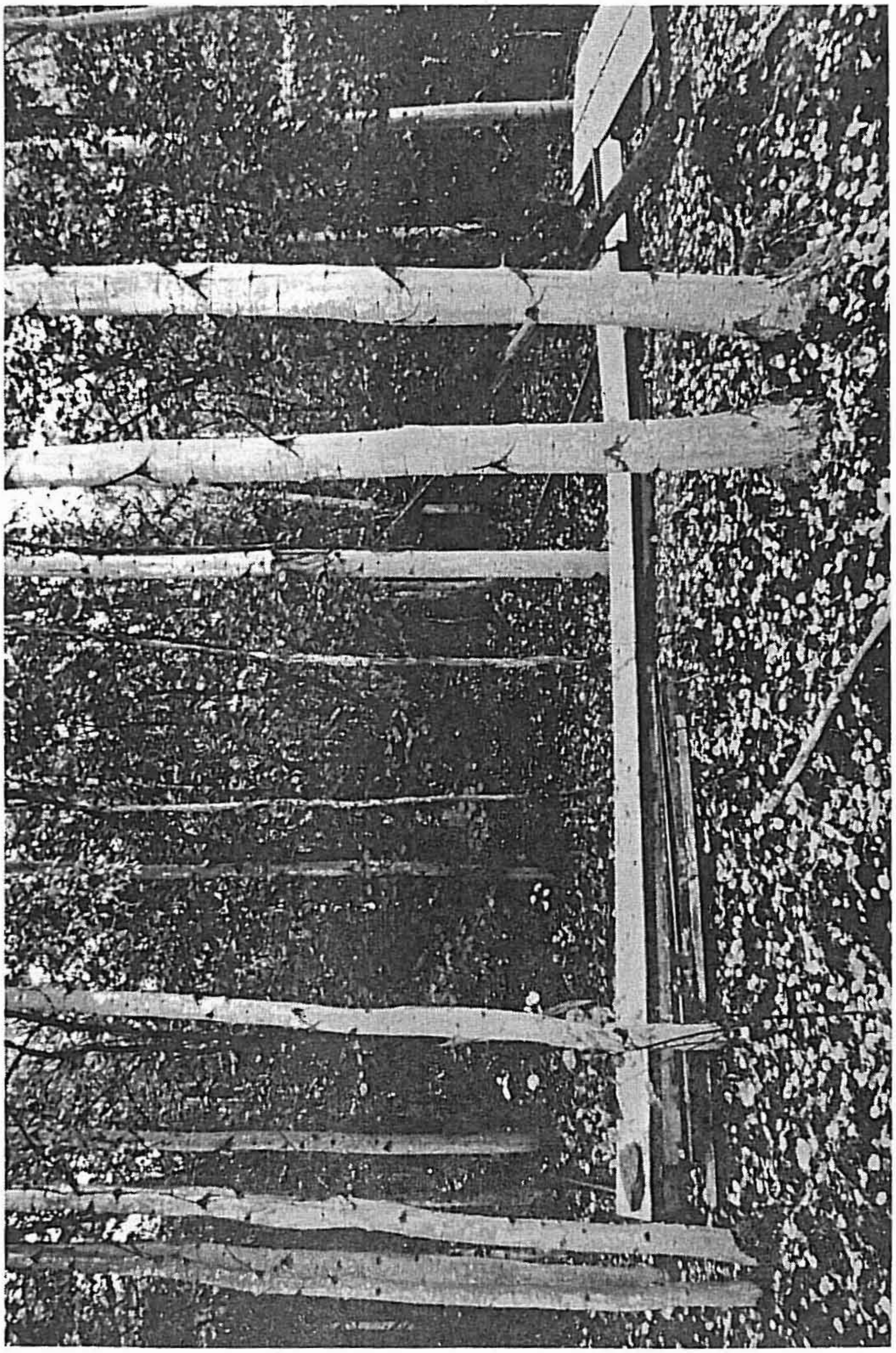


Figure 7: Plot 3 at the Caribou-Poker Creeks Research Watershed.

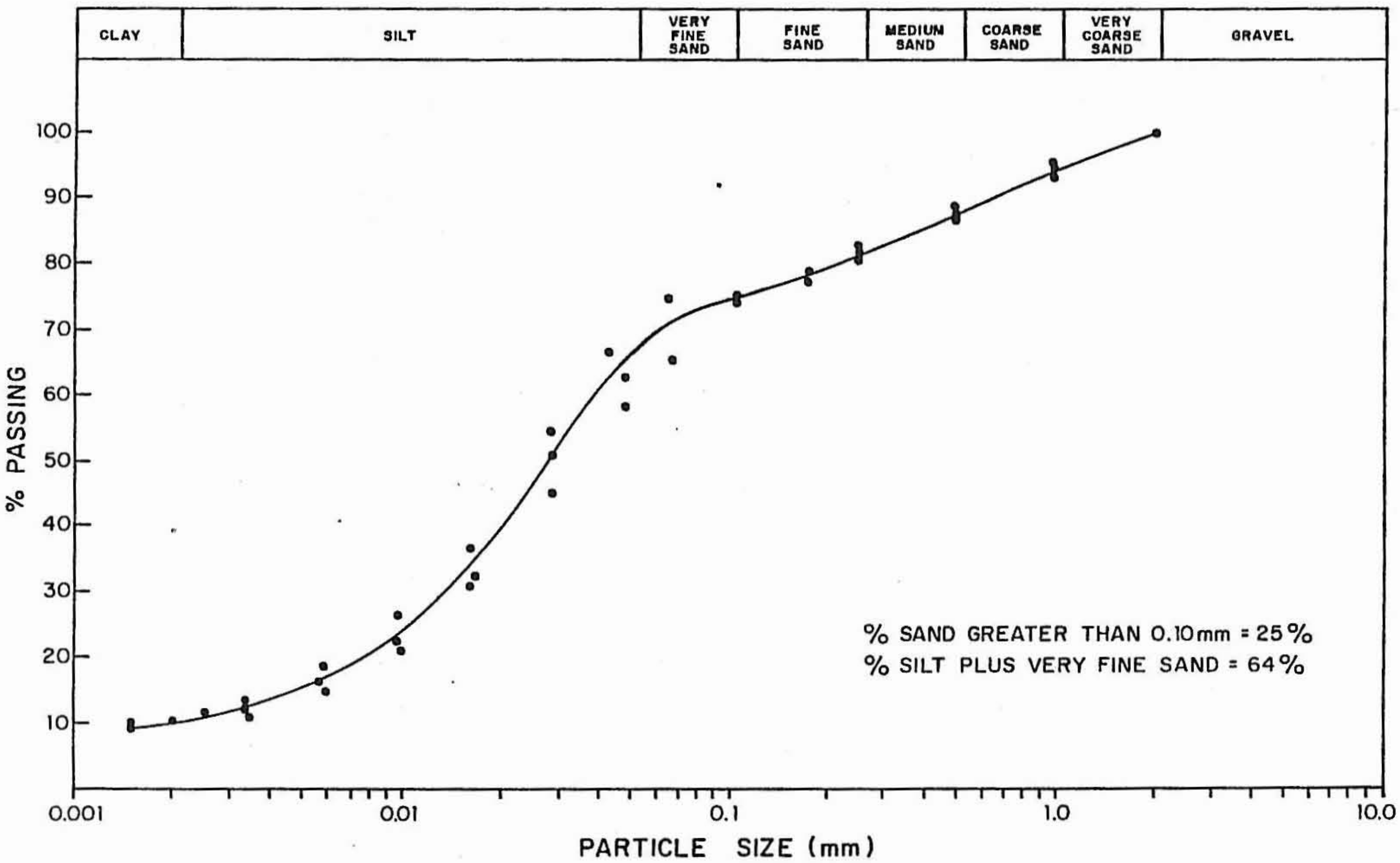


Figure 8: In situ soil gradation for plots 1, 2, and 3 at the Caribou-Poker Creeks Research Watershed.

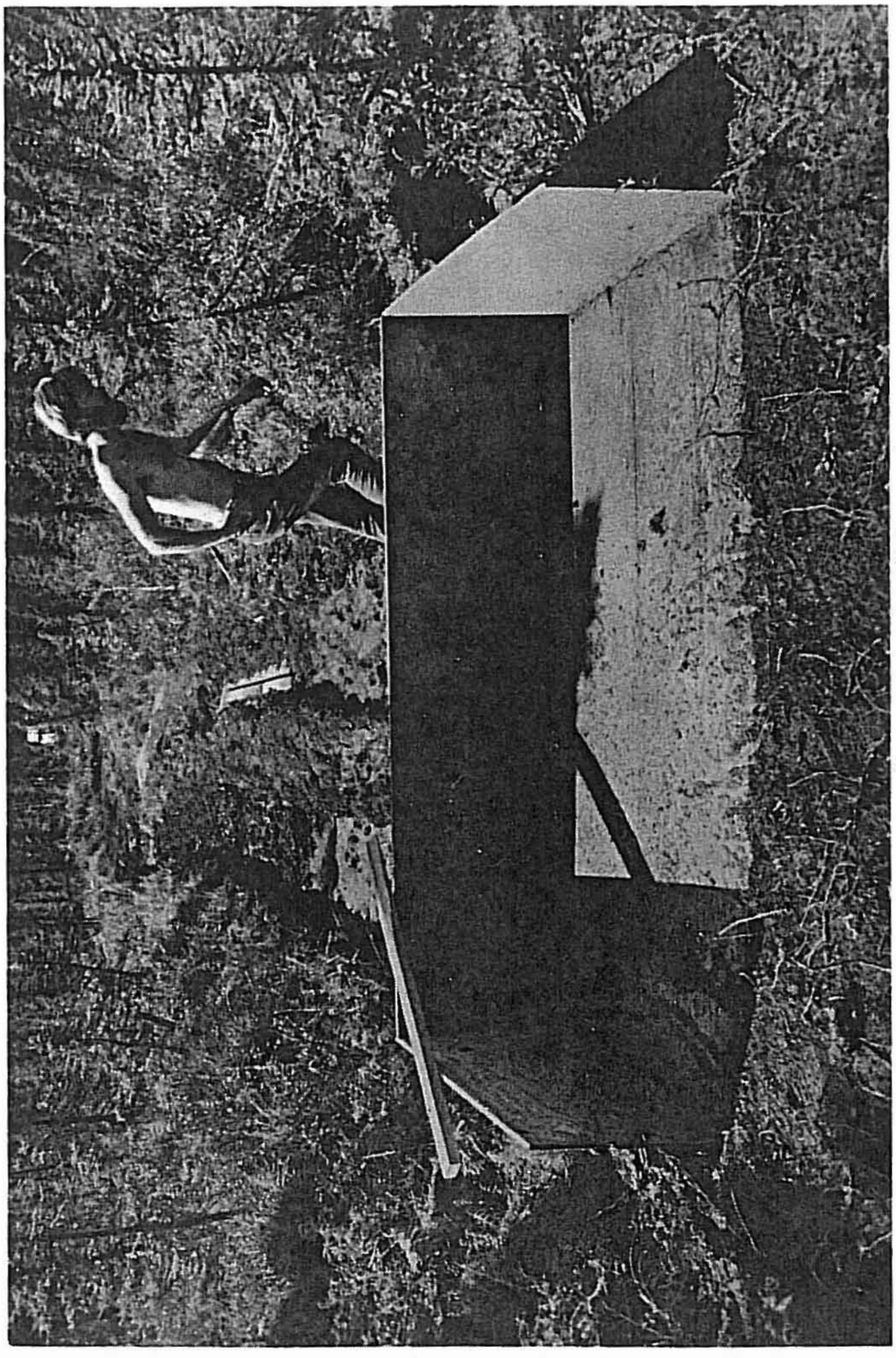


Figure 9: Plot 4 at the Caribou-Poker Creeks Research Watershed.

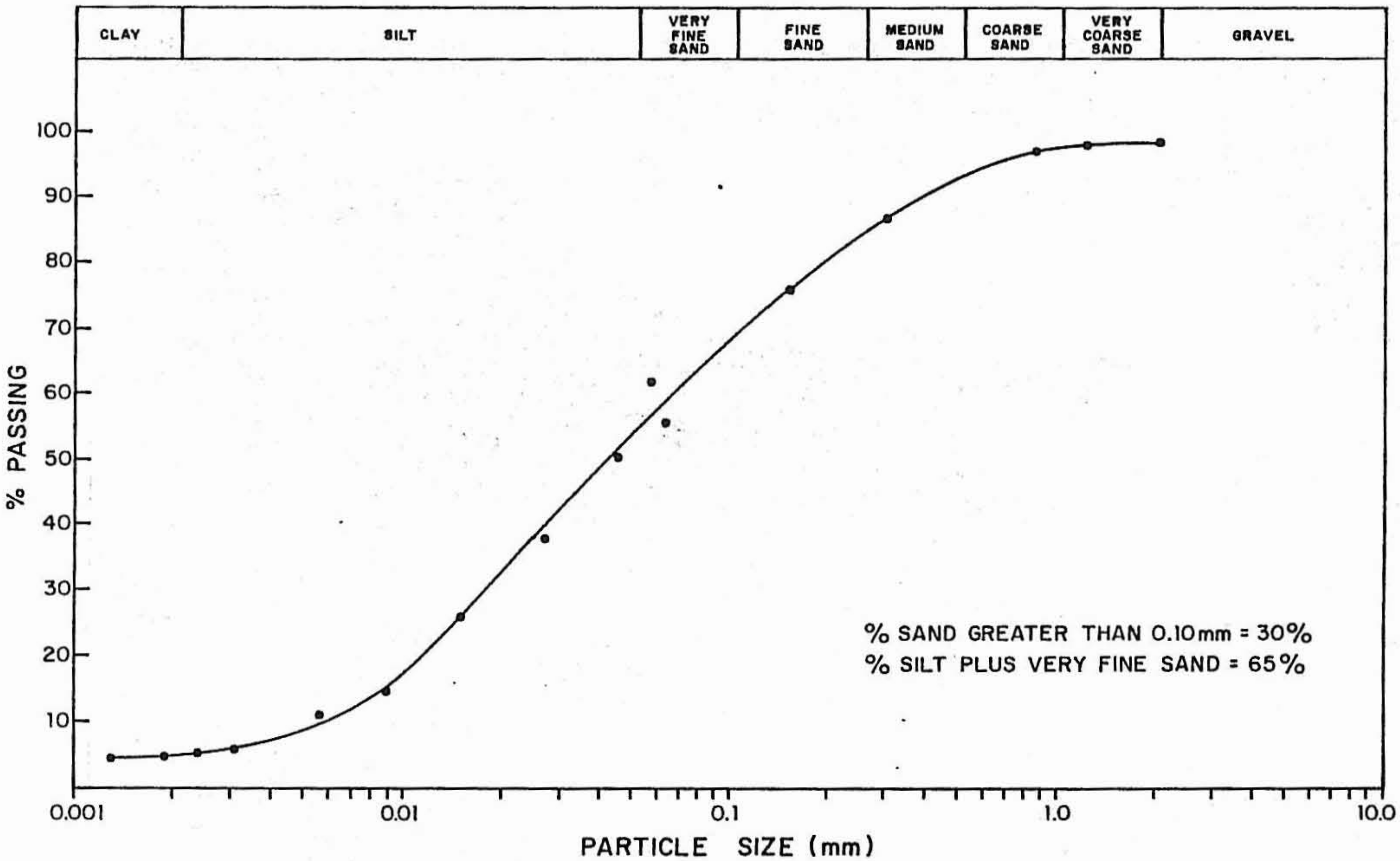


Figure 10: In situ soil gradation for plots 4 and 5 at the Caribou-Poker Creeks Research Watershed.

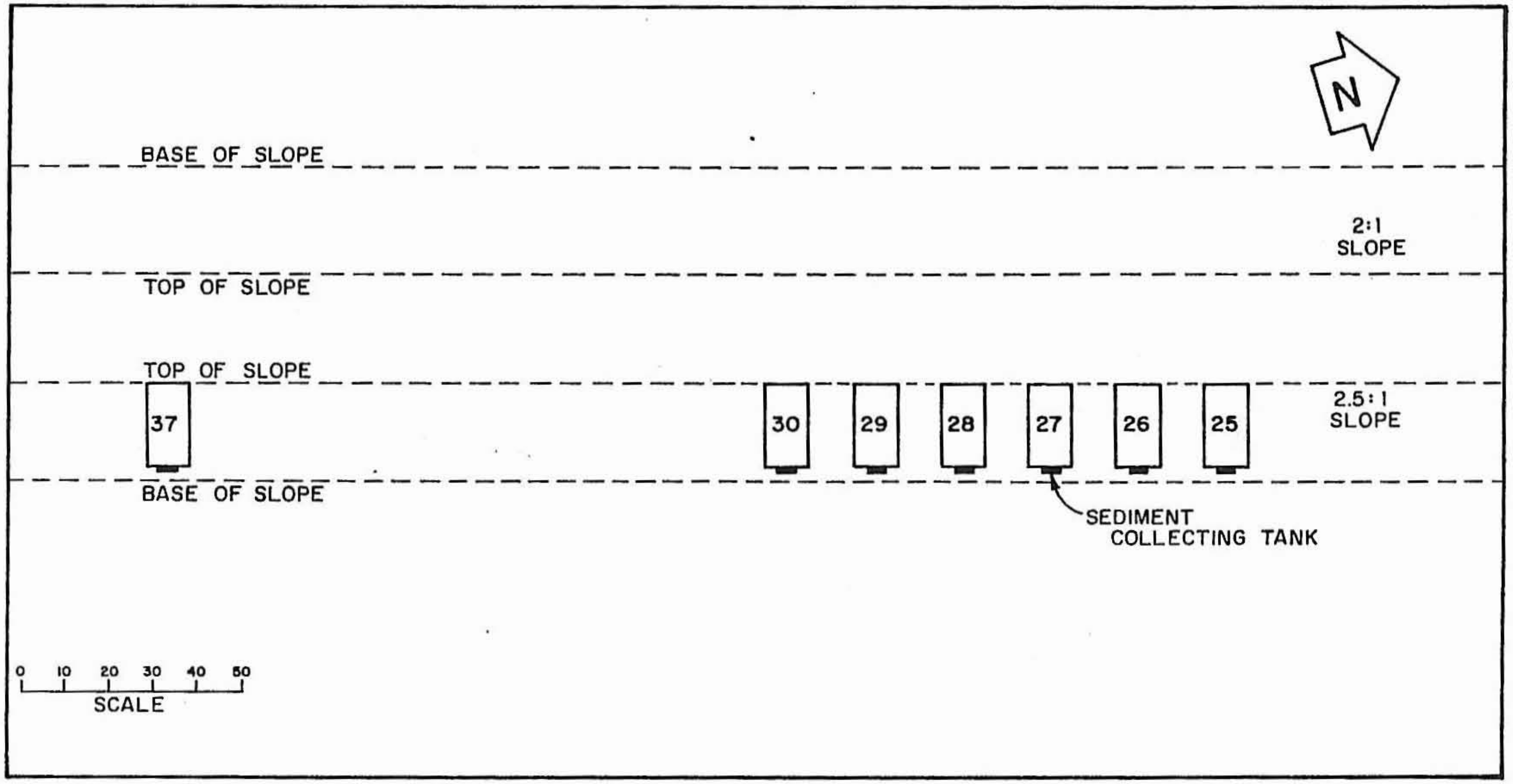


Figure 11: Plan of study site at the Moose Creek Embankment.

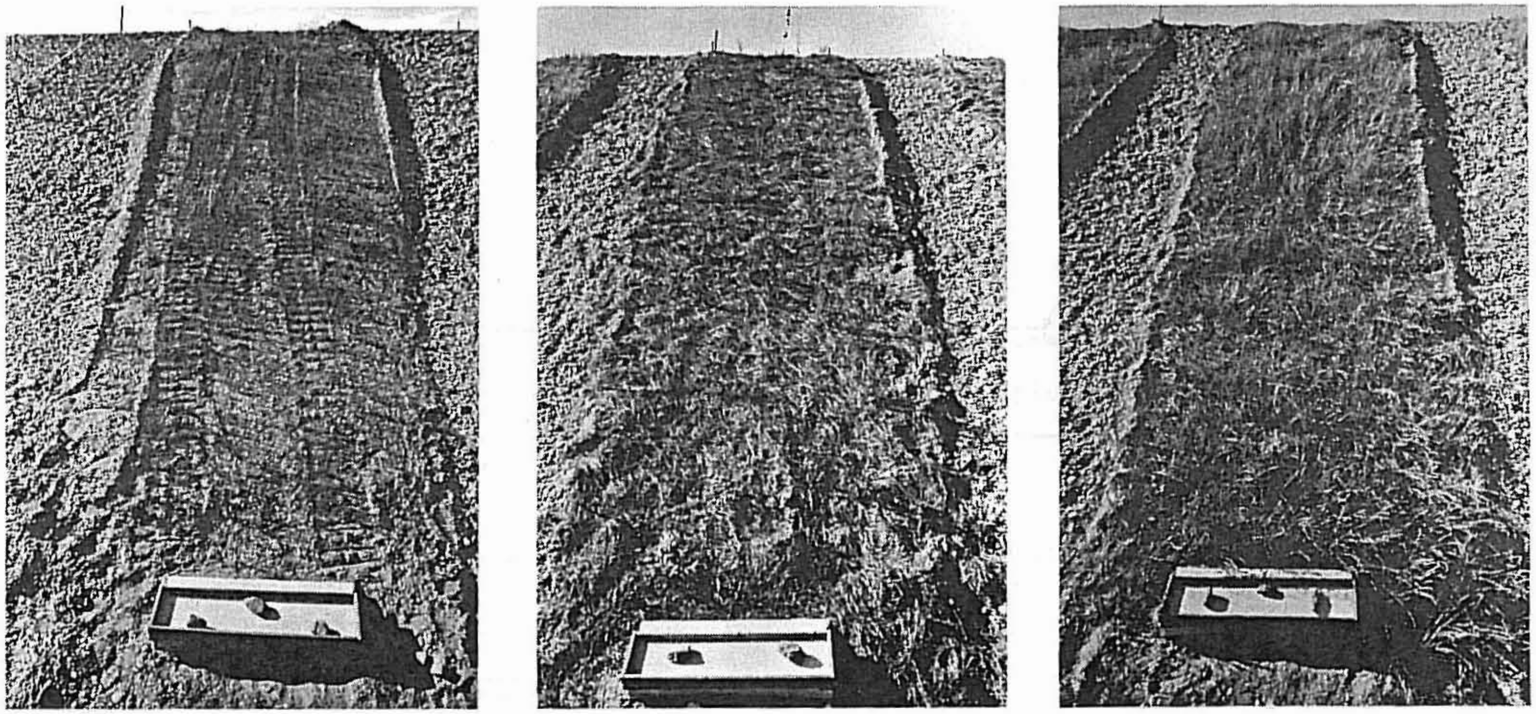


Figure 12: Plots 37, 29, and 27 at the Moose Creek Embankment.

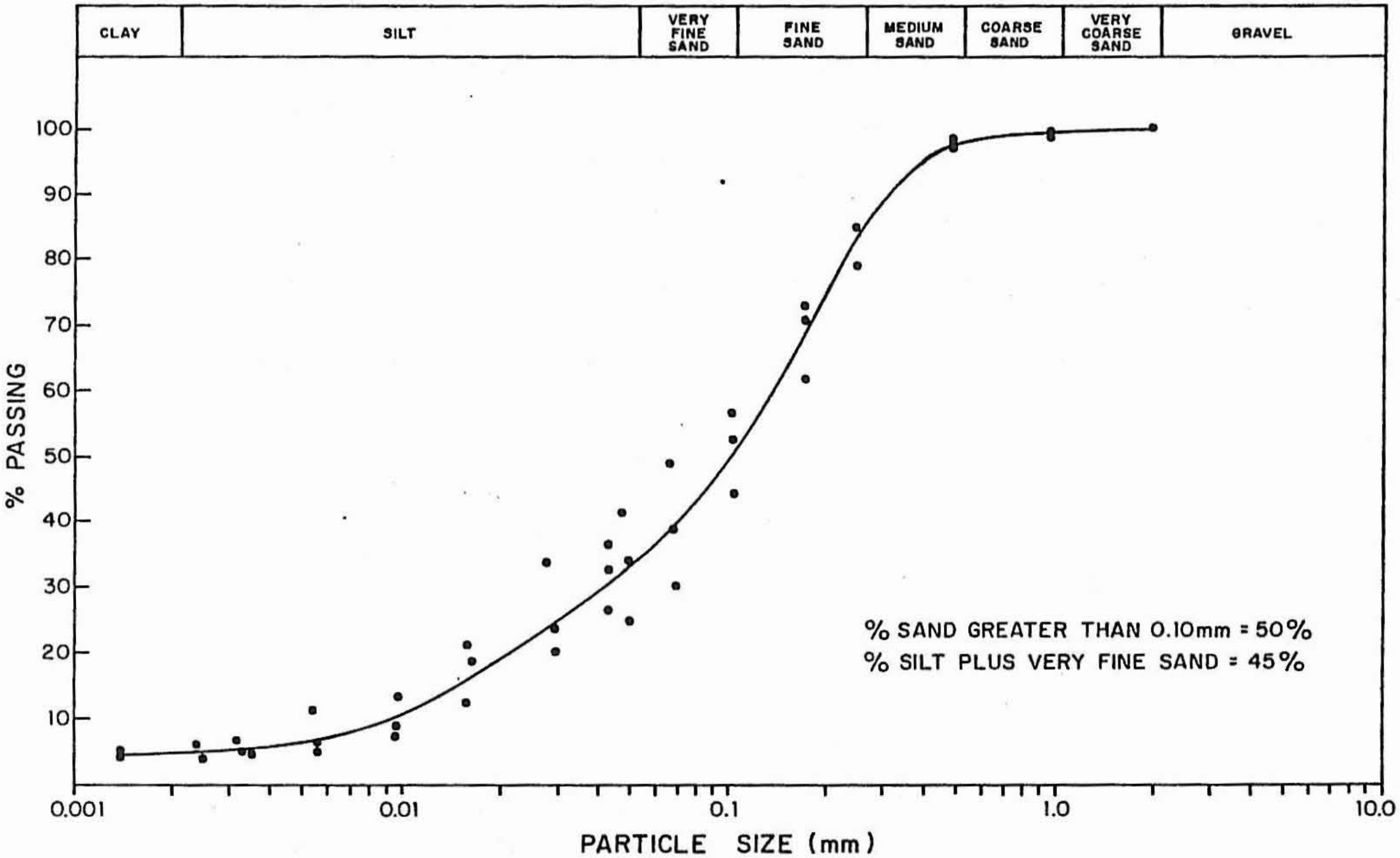


Figure 13: In situ soil gradation at the Moose Creek Embankment.

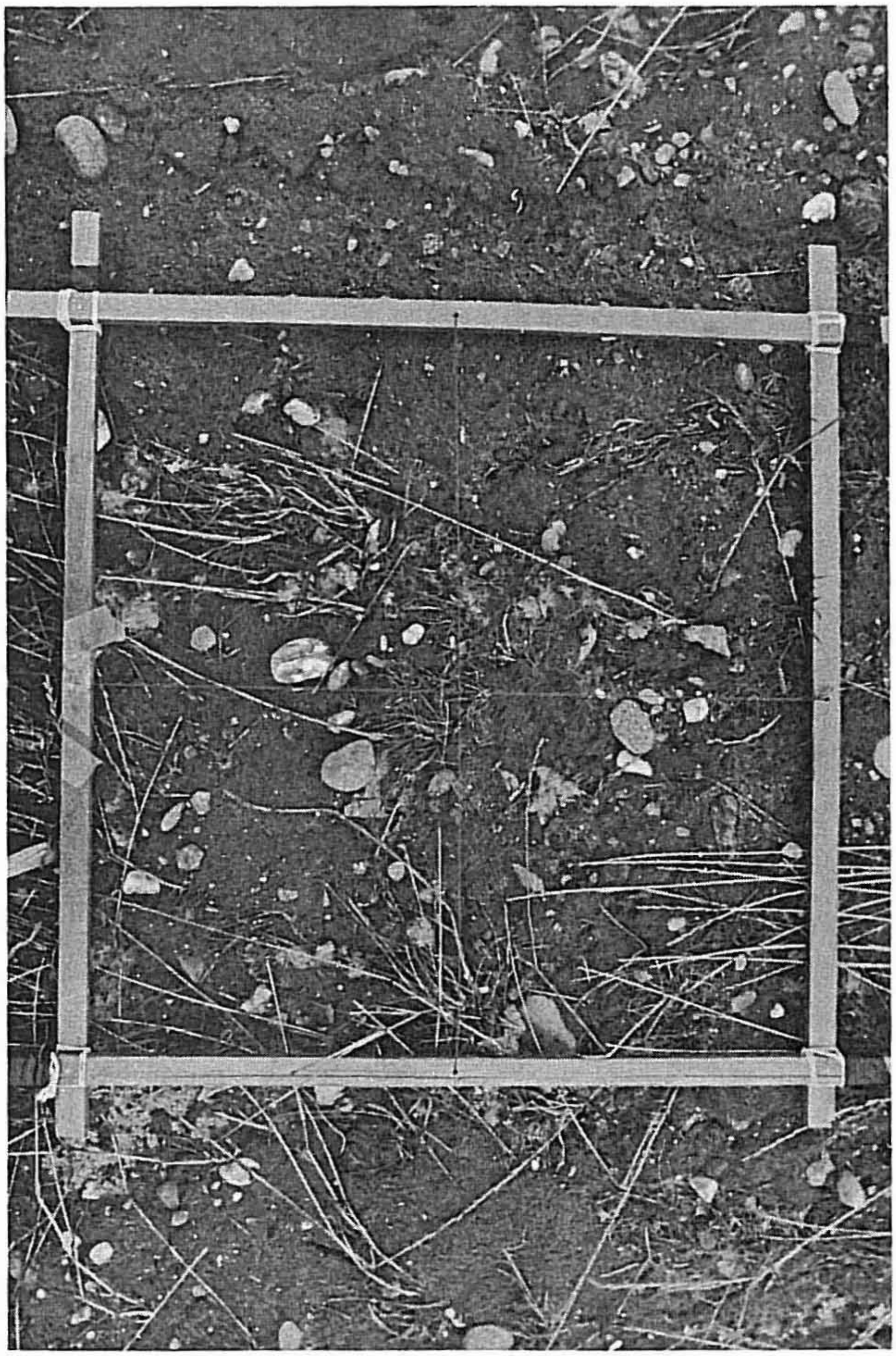


Figure 14: Typical photograph from which percentage of ground cover was determined. Photograph is of plot 37 on June 26, 1978, in which it was calculated that 54 percent of the ground was covered.

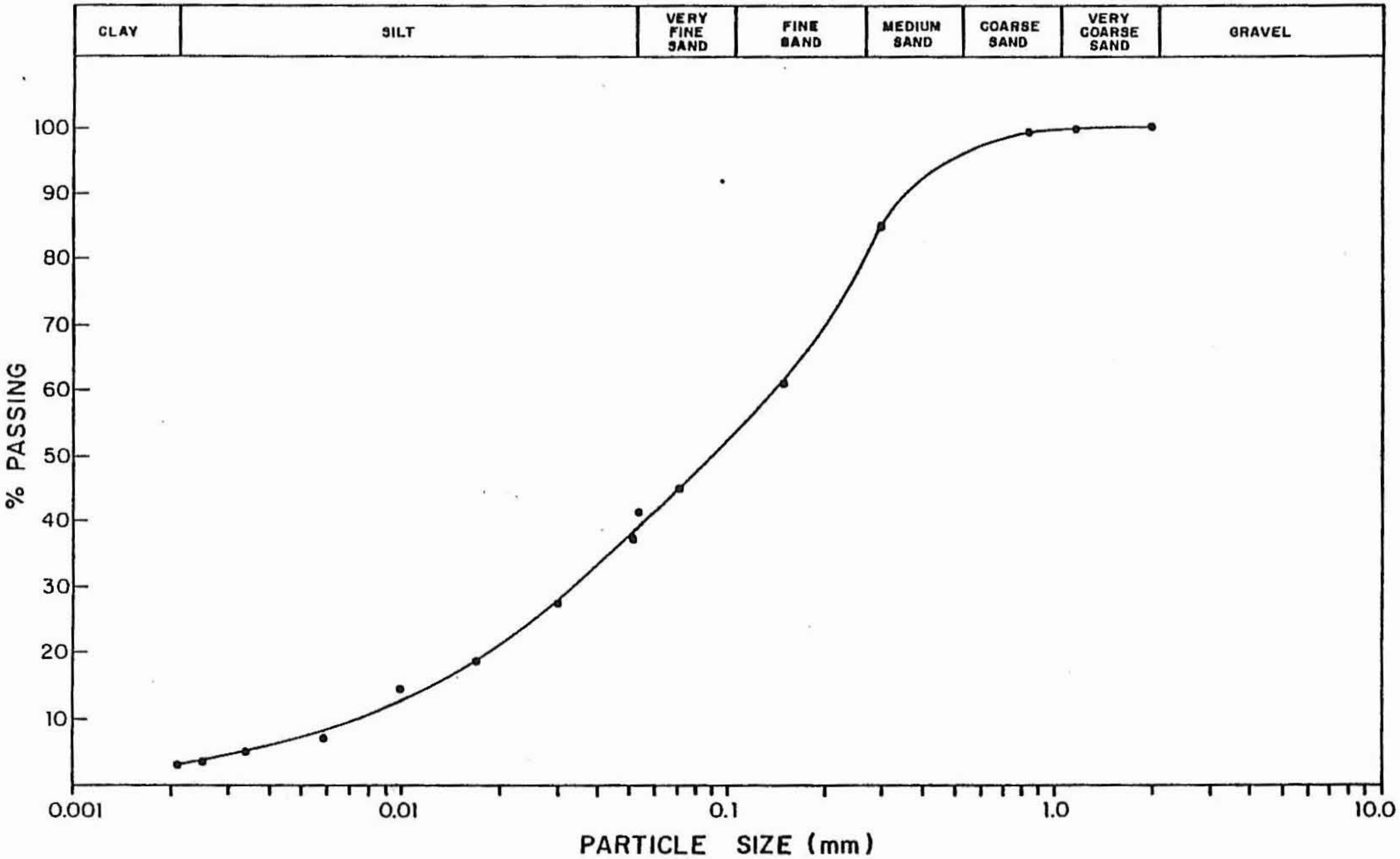


Figure 15: Gradation of eroded soil collected at Moose Creek Embankment Plot 37 on August 30, 1978.

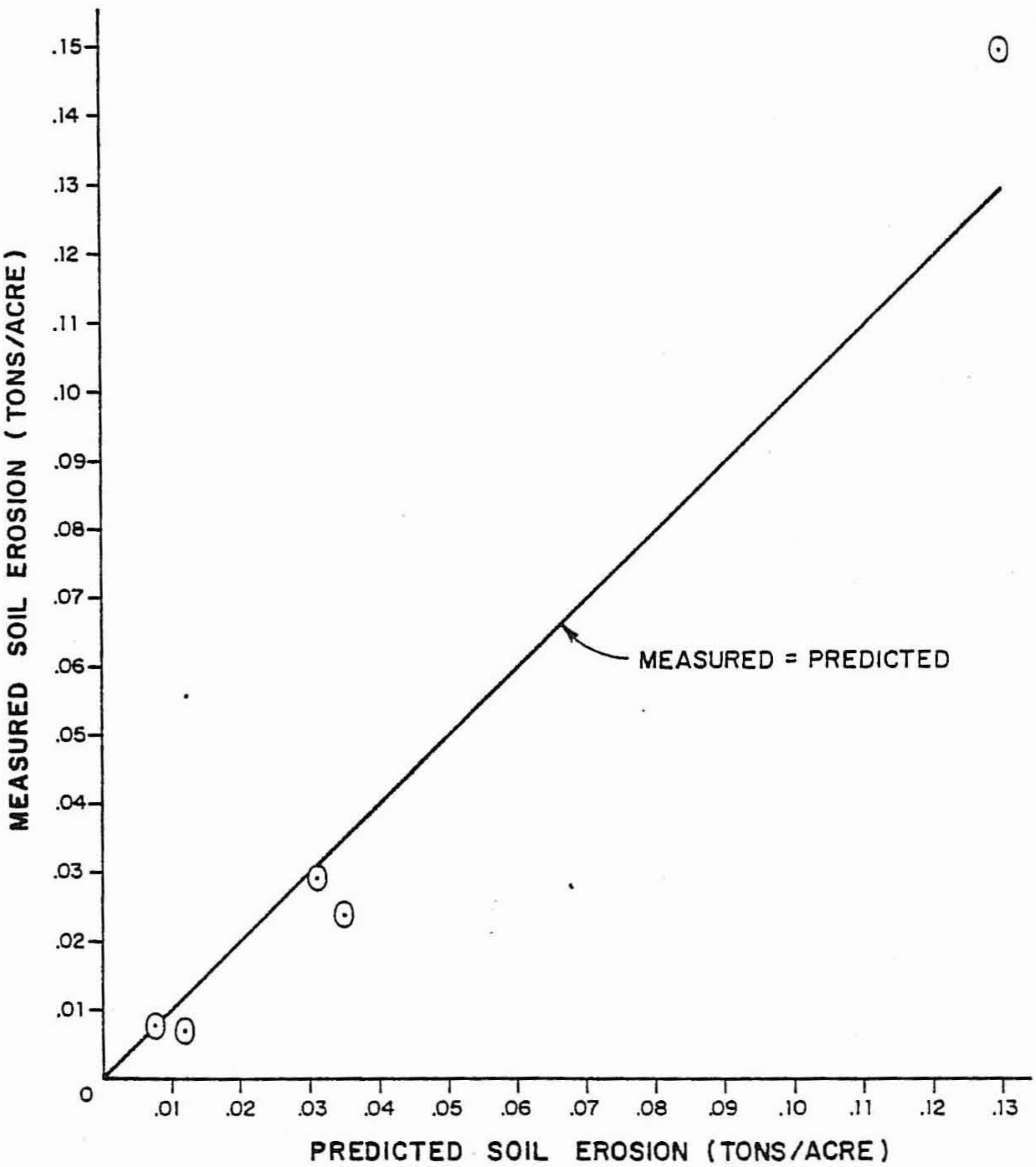


Figure 16: Annual erosion predicted with the Universal Soil Loss Equation versus measured erosion at the Caribou-Poker Creeks Research Watershed.

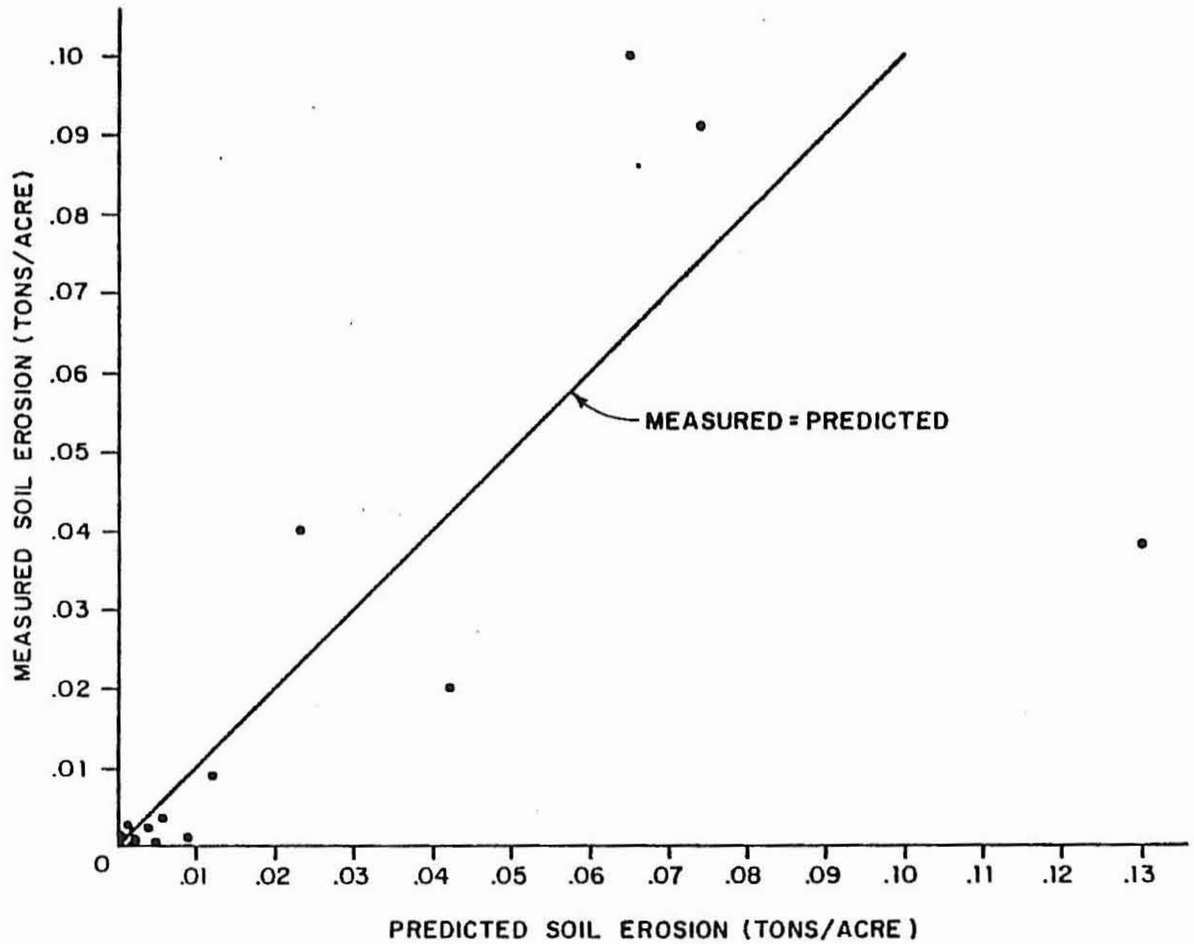


Figure 17: Individual storm erosion predicted with the Universal Soil Loss Equation versus measured erosion at the Caribou-Poker Creeks Research Watershed.

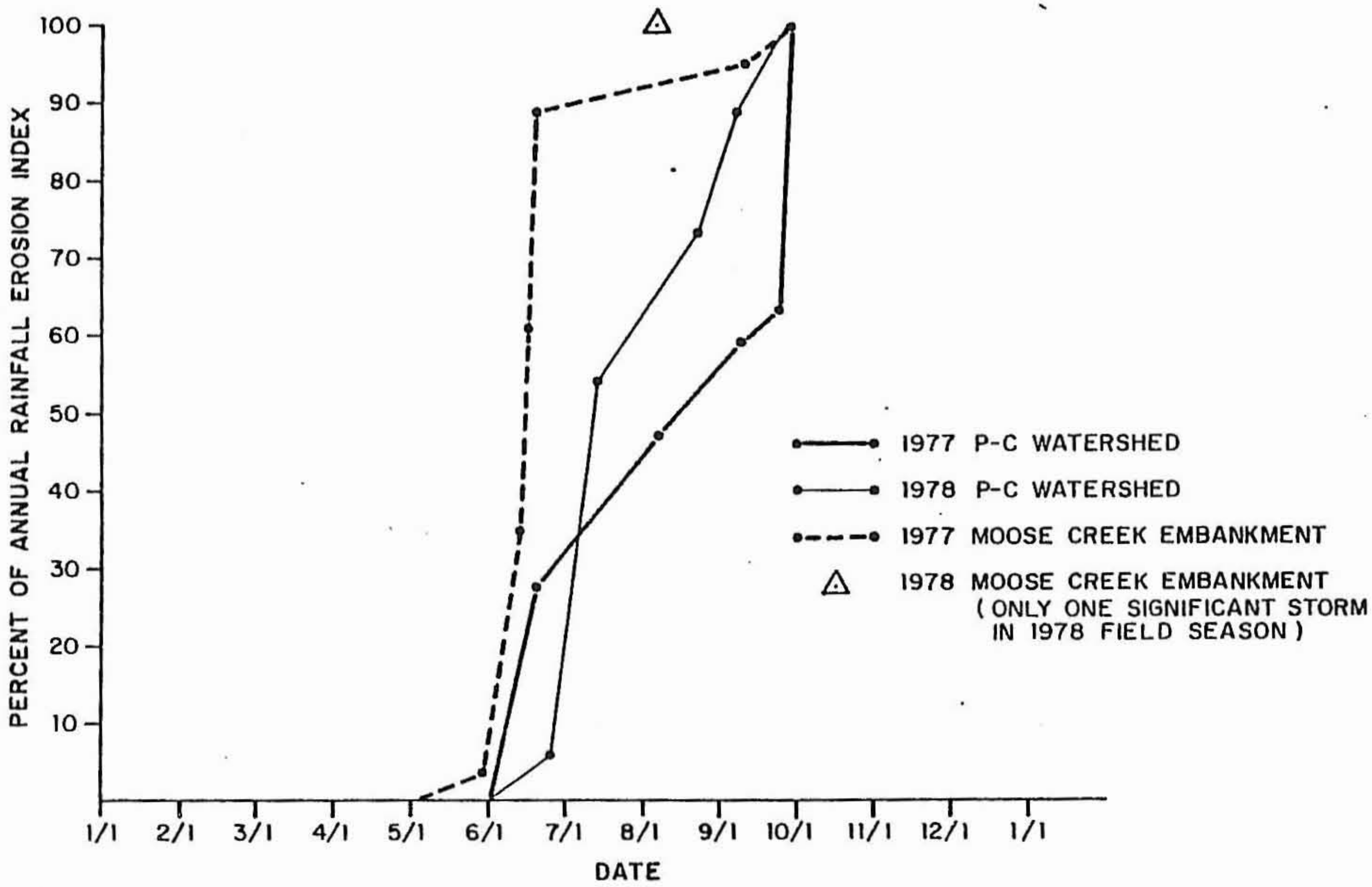


Figure 18: Rainfall erosion index distribution curve. Data from Caribou-Poker Creeks (P-C) Research Watershed and Moose Creek Embankment.

TABLE 1: PERCENT ORGANIC MATTER OF IN SITU SOILS

Plot Number	Mean Percent Organic Matter of In Situ Soil	Standard Deviation (Percent)	Coefficient of Variation (Percent)	Number of Samples	Range
1	7.00	0.15	2.15	3	6.91-7.17
4	12.72	0.56	4.36	3	12.16-13.27
37	5.83	0.44	7.53	3	5.32-6.08

TABLE 2: SUMMARY OF PLOT TREATMENTS

Plot Number	Description of Plot
1	Plot was stripped of all vegetation, leaving a sparse cover of rock fragments over mineral soil.
2	Trees were removed from the plot, leaving a dense cover of club moss and grass.
3	Plot was established in an undistrubed spruce-birch-aspen forest.
4 and 5	Plots were established on churned up spagnum moss in a trail across permafrost.
25, 26, and 27	Plots were established on a steep embankment; planted with unrooted willow cuttings, covered with straw mulch, and fertilized.
28, 29, and 30	Plots were established on a steep embankment; planted with grass and unrooted willow cuttings, covered with straw mulch, and fertilized.

TABLE 3: SOIL ERODED AT THE CARIBOU-POKER CREEKS RESEARCH WATERSHED (tons/acre)

Date	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
7-28-77	a				
8-11-77	0.10[b]				
8-26-77			a		
8-30-77	0.0022		0		
9-9-77	0.020		0.00029		
9-23-77	0.0088		0.00034		
10-7-77	0.038		0.00040		
TOTAL 1977	0.17		0.0010		
5-1-78	a		a		
5-10-78				a	a
5-25-78		a			
5-30-78	0.0012[c]	0.00013[c]	0.0040[c]		
6-30-78	0.0017	0.0014	0.0014		
7-28-78	0.091	0.0037	0.0026		
8-31-78	0.040	0.0011	0.0024		
9-27-78	0.015	0.00097	0.0016	0.03[d]	0.02[d]
TOTAL 1978	0.149	0.0072	o.0080	0.03	0.02

a) Data collection began.

b) The sediment valve has been adjusted according to the portion of the catchment basin which remained in contact with the ground surface during the storm.

c) Represents wind blown sediment only, and is not included in the yearly total.

d) Catchment basin was emptied only once, at the end of the season.

TABLE 4: SOIL ERODED AT THE MOOSE CREEK EMBANKMENT (tons/acre)

Date	Plot 37	Plot 30	Plot 29	Plot 28	Plot 27	Plot 26	Plot 25
5-24-77	a	a	a	a	a	a	a
6-27-77	0.1[b]	0.03[b]	0.03[b]	0.02[b]	0.06[b]	0.02[b]	0.01[b]
7-22-77	0.1	0.003	0.003	0.003	0.003	0.004	0.002
8-8-77	0.02	0.002	0.002	0.002	0.002	0.001	0.0006
8-28-77	7	0.04	0.02	0.04	0.008	0.02	0.03
9-10-77	0.007	0.003	0.003	0.0008	0.0006	0.001	0.0005
9-17-77	0.008	0.0003	0.0006	0.0005	0.0003	0.0007	0.0005
9-24-77	0.005	0.0001	0.0002	0.00009	0.0001	0.0003	0.000006
10-1-77	0.05	0.001	0.0006	0.0007	0.0007	0.0006	0.0008
TOTAL 1977	7	0.08	0.06	0.07	0.07	0.05	0.04
5-1-78	a	a	a	a	a	a	a
5-29-78	0.02[c]	0.008[c]	0.007[c]	0.008[c]	0.008[c]	0.005[c]	0.006[c]
6-29-78	0.01	0.005	0.004	0.004	0.003	0.001	0.001
7-30-78	10	4[e]	0.09	0.4	0.4	2	0.4
8-30-78	1[d]	0.3[e]	0.01	0.1	0.03	0.2	0.04
9-28-78	0.006[d]	0.0006[e]	0.0004	0.0003	0.0005	0.0004	0.0004
TOTAL 1978	10	4	0.1	0.5	0.4	2	0.5

a) Data collection began.

b) Sediment value has been corrected according to the portion of the lip that remained in contact with the ground surface during the storm.

c) Represents wind blown sediment only and is not included in the yearly total.

d) A motorcycle track through the plot diverted runoff and sediment from 36 percent of the plot; the data was corrected accordingly.

e) A motorcycle track was made straight up the plot from the catchment basin.

TABLE 5: MEAN PERCENT GROUND COVER AT THE CARIBOU-POKER CREEKS RESEARCH WATERSHED

Date	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
9-23-77	24		100		
5-30-78	39	84	100		
6-30-78	41	98	100		
7-28-78	38	98	100	69	82
8-31-78	59	99	100		
9-27-78	73	100	100		

TABLE 6: MEAN PERCENT CANOPY COVER AT THE CARIBOU-POKER CREEKS RESEARCH WATERSHED

Date Sample Collected	Plot 3
8-18-77	61
5-30-78	51
6-30-78	82
7-28-78	83
8-31-78	80
9-27-78	31

TABLE 7: MEAN PERCENT GROUND COVER AT THE MOOSE CREEK EMBANKMENT

Date	Plot 37	Plot 30	Plot 29	Plot 28	Plot 27	Plot 26	Plot 25
8-18-77	55	99	100	99	97	99	98
5-29-78	47	86	92	91	86	81	85
6-26-78	67	88	99	97	98	94	98
7-31-78	54	97	96	97	96	97	97
8-30-78	70	90	96	94	92	88	93
9-28-78	61	92	81	88	88	76	78

TABLE 8: MEAN SOIL ERODED FROM REPLICATES AT THE MOOSE CREEK EMBANKMENT

	PLOTS 30, 29, 28[a]			PLOTS 27, 26, 25		
Date	Mean (tons/acre)	Standard Deviation (tons/acre)	Coefficient of Variation (Percent)	Mean (tons/acre)	Standard Deviation (tons/acre)	Coefficient of Variation (Percent)
6-27-77	0.025	0.0023	9.0	0.029	0.023	77
7-22-77	0.0027	0.00023	8.0	0.0026	0.00093	36
8-8-77	0.0017	0.00026	15	0.0011	0.00048	44
8-28-77	0.035	0.014	40	0.021	0.012	57
9-10-77	0.0021	0.0011	54	0.00078	0.00037	48
9-17-77	0.00048	0.00016	34	0.00052	0.00020	38
9-24-77	0.00014	0.000056	40	0.00015	0.00015	110
10-1-77	0.00087	0.00038	44	0.00065	0.000095	150
MEAN 1977	0.068			0.056		
6-29-78	0.0036	0.000076	2.0	0.0020	0.0012	62
7-30-78	0.25	0.23	89	0.79	0.64	81
8-30-78	0.060	0.069	120	0.084	0.084	100
9-28-78	0.00034	0.00013	37	0.00043	0.000046	11
MEAN 1978	0.31			0.88		

a) Due to vandalism, only plots 28 and 29 were averaged for the 1978 field season.

TABLE 9: MEAN PERCENT GROUND COVER FROM REPLICATES AT THE MOOSE CREEK EMBANKMENT

	PLOTS 30, 29, 28[a]			PLOTS 27, 26, 25		
Date	Mean (Percent)	Standard Deviation (Percent)	Coefficient of Variation (Percent)	Mean (Percent)	Standard Deviation (Percent)	Coefficient of Variation (Percent)
8-18-77	99	0.58	0.58	98	1.0	0.01
5-29-78	92	0.71	0.78	84	2.7	3.2
6-26-78	95	5.9	6.2	97	2.3	2.4
7-30-78	97	0.58	0.60	97	0.58	0.60
8-30-78	93	3.1	3.3	91	2.7	2.9
9-28-78	87	5.6	6.4	81	6.4	8.0

a) Due to vandalism, only plots 28 and 29 were averaged for the 1978 field season.

TABLE 10: PERCENT OF SEDIMENT WEIGHT LOST ON IGNITION- - CARIBOU-POKER CREEKS RESEARCH WATERSHED

Date	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
5-30-78	19[a]	70.[a]	71[a]		
6-30-78	15	41	58		
7-28-78	11	62	63		
8-30-78	15	54	67		
9-27-78	28	77	77	50.	64
MEAN	17	59	66		

a) Represents wind blown sediment only, and is not included in the mean.

TABLE 11: PERCENT OF SEDIMENT WEIGHT LOST ON IGNITION- - MOOSE CREEK EMBANKMENT

Date	Plot 37	Plot 30	Plot 29	Plot 28	Plot 27	Plot 26	Plot 25
5-29-78	6.1[a]	6.4[a]	14[a]	14[a]	3.9[a]	14[a]	11[a]
6-29-78	3.3	4.9	8.2	4.6	3.2	6.9	13
7-30-78	2.3	2.7	5.1	3.9	4.4	4.1	4.8
8-30-78	2.2	2.8	8.9	5.1	6.0	3.2	7.3
9-28-78	3.5	28	26	18	19	24	7.7
MEAN	2.8	10.	12	8.0	8.0	10.	8.0

a) Represents wind blown sediment only, and is not included in the mean.

TABLE 12: MEAN 1978 FACTOR VALVES FOR THE UNIVERSAL SOIL LOSS EQUATION - - CARIBOU-POKER CREEKS RESEARCH WATERSHED

Plot Number	Predicted Soil Loss[a]	Soil Factor[b]	Topographic Factor	Cover and Management Factor
1	0.13	0.41	2.43	0.032
2	0.012	0.41	2.43	0.0030
3	0.0079	0.41	2.21	0.0022
4	0.031	0.42	0.82	0.023
5	0.035	0.42	1.92	0.011

a) Expresses in tons per acre.

b) Expressed in tons per acre per increment of erosion index.

TABLE 13: RAINFALL AT THE CARIBOU-POKER CREEKS RESEARCH WATERSHED[a]

Date Rainfall Ended	Total Rainfall[b]	Kinetic Energy of Storm[c]	Maximum 30 Minute Intensity[d]	Rainfall Erosion Index[e]	Rainfall Factor[e]
6-2-77[f]					
6-18-77	0.68	410	0.44	180	1.8
8-6-77	0.71	400	0.30	120	1.2
9-8-77	0.80	430	0.18	78	0.78
9-14-77	0.54	220	0.10	22	0.22
9-26-77	2.42	1300	0.18	240	2.4
TOTAL 1977				640	6.4
4-1-78[f]					
6-24-78	0.65	240	0.10	24	0.24
7-12-78	0.53	380	0.50	190	1.9
8-22-78	1.28	610	0.12	73	0.73
9-6-78	0.68	350	0.18	64	0.64
9-25-78	0.95	450	0.10	45	0.45
TOTAL 1978				396	4.0

a) Only storms of 0.5 inches or more of rainfall are considered.

b) Expressed in inches.

c) Expressed in foot-tons per acre.

d) Expressed in inches per hour.

e) Expressed in foot-tons per acre times inches per hour.

f) Data collection began.

TABLE 14: RAINFALL AT THE MOOSE CREEK EMBANKMENT[a]

Date Rainfall Ended	Total Rainfall[b]	Kinetic Energy of Storm[c]	Maximum 30 Minute Intensity[d]	Rainfall Erosion Index[e]	Rainfall Factor[e]
5-1-77[f]					
5-31-77	0.55	270	0.12	32	0.32
6-13-77	1.05	640	0.40	260	2.6
6-15-77	0.50	360	0.58	210	2.1
6-18-77	0.90	580	0.40	230	2.3
9-8-77	0.79	380	0.14	53	0.53
9-26-77	0.76	320	0.12	38	0.38
TOTAL 1977				823	8.2
5-1-77[f]					
8-5-77	1.01	810	1.44	1200	12
TOTAL 1978				1200	12

a) Only storms of 0.5 inches or more of rainfall are considered.

b) Expressed in inches.

c) Expressed in foot-tons per acre.

d) Expressed in inches per hour.

e) Expressed in foot-tons acre times inches per hour.

f) Data collection began.

TABLE 15: MEAN 1977 AND 1978 FACTOR VALUES FOR THE UNIVERSAL SOIL LOSS EQUATION - - MOOSE CREEK EMBANKMENT

Plot Number	Soil Factor[a]	Topographic Factor	1977 Cover and Management Factor[b]	1978 Cover and Management Factor[b]	1977 Cover and Management Factor[c]	1978 Cover and Management Factor[c]
37	0.24	8.55	0.02	0.06	0.03	0.07
30	0.24	8.23	0.002	0.02	0.003	0.02
29	0.24	8.76	0.002	0.0006	0.003	0.0008
28	0.24	8.74	0.002	0.005	0.002	0.006
27	0.24	8.68	0.004	0.002	0.005	0.003
26	0.24	8.70	0.002	0.01	0.002	0.01
25	0.24	8.68	0.001	0.002	0.001	0.003

a) Expressed in tons per acre per increment of erosion index.

b) Includes the effects of both cover and soil looseness.

c) Includes only the effects of cover.

TABLE 16: MEAN PERCENT GROUND COVER ASSOCIATED WITH TIMBER HARVESTING ALONG THE PARKS HIGHWAY

Activity	Mean Percent Cover	Standard Deviation (Percent)	Coefficient of Variation (Percent)	Range	Number of Samples
Timber Harvest	100	0	0		5
Main Haul Roads	16	14	85	2-48	9
Skid Trails	90	5	5	85-97	6
Log Decks	18	16	86	7-29	2